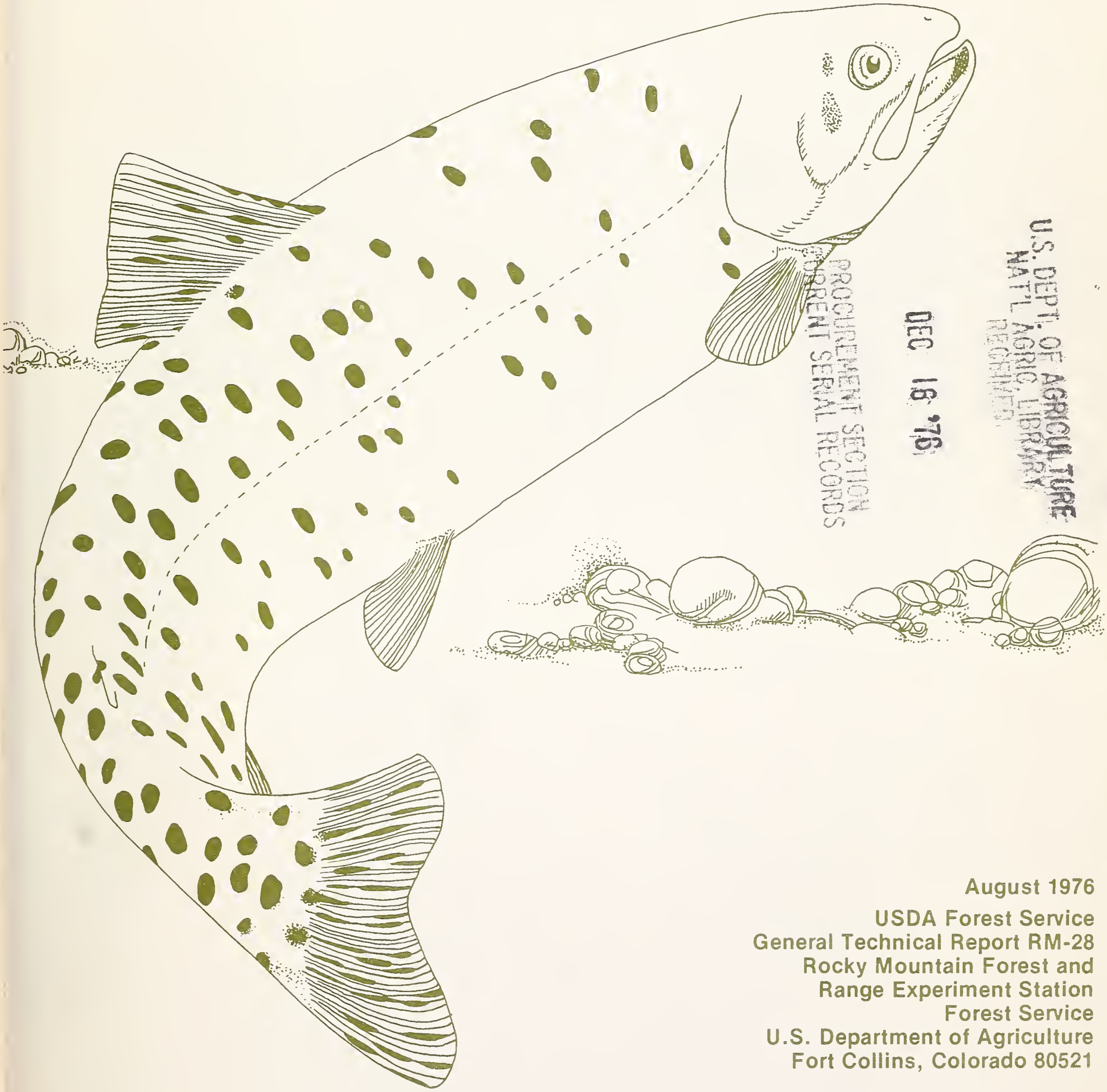
Biology and Management of Threatened and Endangered Western Trouts



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Abstract

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Discusses taxonomy, reasons for decline, life history and ecology, and suggestions for preservation and management of six closely related trouts native to western North America: Colorado River cutthroat, *Salmo clarki pleuriticus;* greenback trout, *S. c. stomias;* Lahontan cutthroat, *S. c. henshawi;* Paiute trout, *S. c. seleniris;* Gila trout, *S. gilae;* and Arizona native trout, *S. apache.* Meristic characters, distribution and status, habitat requirements and limiting factors, protective measures, and management recommendations are presented for each taxon.

Keywords: Native trout, *Salmo clarki pleuriticus, Salmo clarki stomias, Salmo clarki henshawi, Salmo clarki seleniris, Salmo gilae, Salmo apache.*

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INTRODUCTION

This report discusses the biology and management of six closely related trouts native to western North America. All share many common ecological and genetic attributes; all have suffered catastrophic declines in abundance due to essentially similar factors. The following section presents general information applicable to all of these trouts and relevant to any meaningful preservation, restoration and management efforts. Succeeding chapters present more specific biological and management considerations for each taxa.

TAXONOMY

Man still lacks complete knowledge of the evolutionary history which resulted in the diverse array of western North American trouts of the genus *Salmo*. Earlier thought considered that all western trouts either belonged to or recently derived from two evolutionary lines or species: the rainbow trout, *Salmo gairdneri*, and the cutthroat trout, *S. clarki*. Recent studies have demonstrated that the true situation is much more complex; several distinct groups including the Gila trout (*S. gilae*), Arizona native trout (*S. apache*), Mexican golden trout (*Salmo chrysogaster*), California golden trout (*Salmo aguabonita*) and redband trout (not officially named) do not fit the diagnosis of either the rainbow trout or the cutthroat trout and probably represent distinct evolutionary lines of their own which sprang from a common ancestor to all western *Salmo* (Behnke 1972b, Schreck and Behnke 1971, Miller 1972).

Despite such evolutionary diversity, all western trouts are closely related to the extent that they can interbreed freely with each other to produce fertile hybrids. Only in Pacific Coast rivers, where rainbow trout and the coastal cutthroat, *S. c. clarki*, reside together and in the Salmon and Clearwater drainages of the Columbia River basin of Idaho where resident interior cutthroat occur with anadromous steelhead trout (*S. gairdneri*) does coexistence occur naturally without hybridization. In all instances where the rainbow trout has been established beyond its native range and stocked with Gila trout, golden trout or any of the interior subspecies of cutthroat trout, hybridization has invariably resulted. The indiscriminate stocking of untold millions of rainbow trout and several subspecies of cutthroat trout into virtually every habitable water throughout the West, and subsequent hybridization with the native trout fauna, has been the primary cause for the almost complete elimination of pure populations of most of the taxonomic categories of native trouts in the interior regions of the West.

The presence of all degrees of hybridization greatly confounds the work of correctly identifying and evaluating the purity of existing populations of native trout in most regions, and the recognition of pure stocks of any of the six trouts considered in this report is not a simple matter. Although one can acquire sufficient familiarity with the subtle variations among the different species and subspecies of western trouts to distinguish the various taxa, the average field worker cannot be expected to accurately differentiate the true native trout of a given area from hybrid populations. Taxonomic criteria exist for all the trouts in this report, but the sorting and evaluation of specimens collected during survey work to determine the status of a native trout and to locate pure populations remains an involved process of detailed examination and comparison of many characters.

So unless an agency is dealing with "certified" pure populations in a rare trout management program, it will ultimately confront the problem of identification. Possibilities for additional refinement of information useful in taxonomic identification exist; these include biochemical techniques such as protein electrophoresis and karyotype examination--the determination of chromosome number and morphology. Yet the investigator should use caution in utilizing these modern techniques

to determine the relative purity of trout populations, for they require both a knowledge of basic principles of taxonomy and a familiarity with the natural range of variability of the trout under study. Often, if the extent of hybridization has reached a level where it can be detected by electrophoresis or alterations in the chromosome complement, it will also show up in the form of changes in dentition, spotting pattern, scale counts and other morphological characters.

The lack of reproductive isolation and the lack of clear-cut diagnostic features, has raised questions concerning the validity of the recognized taxa of western trouts. The most pertinent advice relevant to management policies for any trout under consideration is to ignore or avoid questions concerning the validity of zoological nomenclature, while recognizing that each of these trouts is indeed an evolutionary reality. That is, it has become an integral part of the biological and evolutionary heritage of a given geographical area as a result of its unique genetic programming under the natural selection which has taken place during its long isolation and divergence from ancestral trout fauna. All of the six taxa of trout discussed in this report fall within the province of the Endangered Species Act of 1973 (P.L. 93-205) which defines a species to include "subspecies, smaller taxa or any population segment thereof." Thus, the validity of a species or subspecies should not obstruct protective measures for a rare trout; the major consideration ought to be that the trout represents a segment of a species indigenous to a particular geographical area.

Behnke (1972a) and Trojnar and Behnke (1974) have discussed the rationale and practical value of preserving the remaining genetic diversity of our native western trouts.

REASONS FOR DECLINE

We mentioned that the hybridization caused by massive introduction of rainbow trout and subspecies of cutthroat trout into waters in which they were not native has led to the virtual elimination of pure populations of the trouts under discussion in this report. Habitat loss and degradation as a result of irrigation projects, mining, logging, road building and overgrazing have also taken their toll, particularly in the arid regions of the West. These factors have not only greatly reduced the amount of suitable habitat, but also favor the displacement of native trouts by more tolerant introduced species, notably the brook trout (*Salvelinus fontinalis*) and the brown trout (*Salmo trutta*).

Most pure native trout populations in the interior regions of the West persist only in small isolated headwater stream situations in essentially undisturbed habitat.

LIFE HISTORY AND ECOLOGY

All of our western trouts are highly adaptable; they can live in a variety of environments ranging from small brooks to large rivers and lakes, and they feed on a broad spectrum of organisms. This wide range of adaptability makes it highly misleading to base the ecological characteristics of an entire taxon on data taken from a population in a specific habitat. All trouts are opportunistic and eclectic in their diet, which essentially reflects the availability of food organisms in their particular environment. Growth depends primarily on food availability, size of prey, the degree of intraspecific and interspecific competition, water temperatures, and the length of the growing season. Fecundity, in turn, depends on size. The life history and ecological traits of two neighboring populations of the same subspecies living in distinctly different environments will differ much more from each other than from those of different trout species living in essentially similar environments. One must be aware that different genotypes allow for a broad and labile range of ecological options; to assume that specific food habits, growth rate, fecundity or other characteristics of a given population under study represent genetically "fixed" attributes of the taxon as a whole is a misconception. The significance of this point in relation to restoration efforts which aim to expand the range of a rare trout is that waters with potential for reintroduction need not closely match the conditions of the waters of the potential donor population. With the condition that no non-native trouts are present, virtually any waters suitable for any trout species can serve as suitable habitat for any of the six trouts treated in this report. One notable exception in adaptability to environmental extremes exists in the Lahontan cutthroat trout, which can tolerate tremendous ranges in alkalinity and flourish in waters such as Walker Lake, Nevada, under conditions lethal to all other trouts.

All of the non-domesticated western trouts of the genus *Salmo* spawn in the spring; increasing water temperatures trigger reproduction. Most spawning activity begins when

water temperatures reach 5.5 - 9.0° C. Elevation and latitude also influence the onset of spawning, which may occur as early as March or April in some areas and extend well into June and July in others. The necessity of gravel for nest construction and high oxygen tensions for the developing embryos makes all of the trouts under consideration essentially obligatory stream spawners. Fry emerge from nests in early to mid-summer, depending on when spawning occurs; length of the growing season dictates size, which reaches 2.5 to 7.5 cm by autumn. Fish six to eight years old may attain a length of less than 25 cm in small streams with restricted habitats and dense populations, but in large rivers and lakes growth can be rapid with trout reaching several pounds in weight by the fourth or fifth year. The last spawning run, in 1938, of the native cutthroat of Pyramid Lake, Nevada, revealed an average weight of 9.0 kg for spawning fish, most of which were seven to eight years old (Sumner 1940); trout of the same subspecies living in headwater streams may not exceed 25 cm in length.

Sexual maturity typically occurs at an age of two to four years. In small stream populations mature trout may only be 15 to 20 cm in length and spawn only 100-200 eggs. A generalization on fecundity, with wide individual variation, is that females will spawn about 1000 eggs per 450 gms of body weight.

Present populations of these trout probably cannot persist in waters where maximum temperatures consistently exceed 21-22° C. But they may possess tolerance to survive, under stress, brief daily periods of higher temperatures (25.5 - 26.7° C.) if the waters significantly cool at night. The pattern of replacement of native trouts by introduced brook, brown and rainbow trout throughout the interior West indicates that the native trouts prefer and function best at lower temperatures than do other species. With few exceptions, native cutthroat trout coexist with and dominate introduced species only in cold, headwater situations. Thus, clearcutting and overgrazing, which remove vegetative cover and warm the waters, will favor the replacement of native trouts by other forms.

In Oregon, after clearcutting of a watershed, water temperatures increased due to lack of cover, and dissolved oxygen in the spawning gravel decreased due to siltation. This did not significantly affect the coho salmon population, but the cutthroat trout population suffered a decline of two-thirds in number during six years of a follow-up study (Ringler and Hall 1975).

Cutthroat trout, and perhaps Gila trout and Arizona trout as well, suffer from a high vulnerability to angling. In a small Idaho stream, 32 man-hours of fishing removed 50 percent of the cutthroat trout and only 25 percent of the brook trout 15 cm and over in length (McPhee 1966). In New Mexico the native trout of the Rio Chiquito dominated the introduced brown trout by 420 to 37 in samples made in 1965-1966, when the stream was on private land and closed to fishing (Little and McKirdy 1968). In 1969, two years after the U. S. Forest Service had acquired the land and opened the stream to angling, sampling revealed that the ratio had been drastically reversed--137 brown trout versus 37 cutthroat trout--due to the differential vulnerability of the two species to angling[1/]. Management programs for native trout can benefit from this angling vulnerability, however, by establishing special regulation catch-and-release fisheries, or by restricting size and bag limits, as discussed below (see pages 7-8).

PRESERVATION, RESTORATION AND MANAGEMENT PROGRAMS

It often seems difficult to initiate meaningful rare trout restoration programs, but while real problems and obstacles exist, workers can overcome them if they develop a set of priorities and goals and recommend that specific actions be carried out. It remains a relatively simple matter to transplant trout from a remnant population into new waters--either barren or where all other fish have been eliminated--in order to establish a new population.

The first step in most restoration programs for rare, native trout--that of identification--involves a survey and inventory of waters where there is a likelihood of encountering pure populations. Remote and isolated headwater areas, particularly above barrier falls and without tributary lakes (which serve as popular target areas for introductions of exotic trouts), offer the greatest potential for native trout population reserves. When trout in such waters appear to resemble the diagnosis of the native trout, collect 10-20 specimens from each isolated site and preserve them in 10 percent formalin. In the field, wrap specimens in formalin-soaked cloth and inject formalin into the body cavity with a hypodermic syringe. Comparative examination of these collections can begin to identify

1/ McKirdy, H. J. Rio Chiquito population survey. Carson National Forest memorandum. 22 August 1969.

those populations most closely conforming to the diagnosis of the taxon involved. Graduate research thesis projects through universities can offer relatively efficient and economical means of handling survey and identification work. Once researchers establish the relative purity, distribution and abundance of the native forms, those populations judged to be uncontaminated by hybridization can be given special consideration in land use decisions and environmental impact analysis, and serve as a source for specimens for introductions to increase their abundance.

Unnecessary delays and procrastination typically begin at this stage, when specific native populations have been identified. Many believe that they must initiate life history and habitat studies before any management decisions or transplants can take place. The objectives are to gather detailed data on age, growth, food habits, fecundity and other life history characteristics of the trout population, and on the biological, physical and chemical parameters of the waters in which they live, with the idea that once this knowledge becomes available intelligent and scientific management can begin. If the life history characteristics of trout were genetically fixed traits, and if the environmental parameters measured composed a true reflection of the limits for survival, this would be a logical course of action; but in fact they are not. Such information usually has little meaning when predicting the success of a transplant into new waters, except where basic information is needed to maintain an abundance of trout and a desirable age structure in a population exposed to exploitation in a special regulations fishery program.

If a survey determines that pure populations of a native trout are rare and restricted to a few isolated stocks, then first priority should be to effect transplants into new waters within their native range, before natural or man-caused catastrophes can further decimate the remnant stocks. After the establishment of populations in new waters, life history studies and environmental analyses can include both donor and recipient populations and their environments. Such information would have greater predictive value since it would offer more insight into the range of adaptive responses of the trout under study.

Naturally barren waters above barriers, which prevent mixing with introduced trouts, constitute ideal sites for establishing new populations. Such locations still exist, though they are rare. The expense and efforts of effecting a transplant of this nature involves only the collection and transport of live fish. Note that some barren headwater streams, particularly at high elevations, appear to provide suitable habitat for trout in summer, but lack pools and cover sufficient to successfully carry the fish through a hard winter. In these situations the trout migrate from the area and will not maintain a permanent population (Bjornn 1971). Habitat improvement in headwater areas is feasible when it involves creating pools and cover to provide support for a permenent fish population (Gard 1961, 1972).

Many more streams exist which support introduced trouts or hybrids above a natural barrier; they too offer good possibilities for establishment of native trout populations with minimal effort and expense. No doubt exists that these streams can support the transplanted trout after the complete elimination of all other fish. Use antimycin or rotenone in small streams to completely kill all fish, taking care to treat all possible refuge areas such as backwater areas of beaver ponds and spring seeps. The National Park Service used this technique in Rocky Mountain National Park in eliminating the brook trout from Hidden Valley to re-establish the greenback cutthroat trout.

If no natural barrier exists on an otherwise suitable stream, it is possible to construct an artificial barrier or to blast one out of a rock substrate. Follow barrier construction with chemical treatment above the stream, to eliminate unwanted fishes, before the introduction of native trout. Workers used this technique to re-establish greenback trout in Black Hollow Creek, Colorado, and Gila trout in McKnight Creek, New Mexico.

Another viable possibility in any rare trout reintroduction program is the establishment of populations in newly constructed lakes to establish a unique fishery under special regulations. Christmas Tree Lake on the Apache Indian Reservation, Arizona, stocked with Arizona native trout, serves as an example of this method. Lake populations offer an abundant and easily obtainable source of eggs for propagation, and can greatly facilitate new introductions.

Some difficulties may exist in establishing a new population from transplants of a few adult fish into a new environment, particularly in small headwater streams without deep pools above a barrier. The natural tendency of a displaced fish is to return to the place of its origin, and most may soon migrate downstream over the barrier. Trout movement is also more pronounced during periods of low or decreasing temperatures (Bjornn 1971). Once

natural reproduction has occurred in the new environment, the success of the introduction should be assured, barring some catastrophe.

Particularly in arid regions where streams characteristically display intermittent summer flows and lack suitable pools and cover, stream improvement devices can promote increased abundance of trout by creating trout habitat where none previously existed. Stream improvement devices often require a considerable investment of money, time and labor, but the construction in the 1930's of such devices in Diamond Creek, New Mexico, by Civilian Conservation Corps personnel may have saved the Gila trout in this stream from extinction during subsequent drought years when virtually the entire population was restricted to the pools created by the small dams.

Successful stream habitat management improves living conditions in the waters and increases survival, growth and reproduction of trout. Good trout habitat provides shelter from predators, fertile water, adequate living space, proper water temperature, and gravel in the streambed for spawning. Proper stream management, especially when it involves the construction of in-stream improvement devices, is both relatively expensive and relatively complicated, and remains a job for professionals who are both well-versed in fundamental trout ecology and familiar with habitat management techniques. Every stream has its individual problems and characteristics, and to proceed with habitat alteration projects to "improve" a stream without a thorough knowledge of available methods, the physical, chemical and biological parameters of the waters in question, and the ecological characteristics of the resident fish population, can do more harm than good. A habitat improvement team should consist of biologists skilled in habitat development, technicians familiar with surveying and mapping techniques, and foremen experienced in carpentry and mechanics (White and Brynildson 1967). Space does not permit a thorough discussion of habitat improvement techniques here; several excellent papers exist to familiarize personnel with this topic (see: Boreman 1974, Packer 1957, Jester and McKirdy 1966, Gee 1952, Hunt 1969, White and Brynildson 1967, Jackson 1974).

A survey of streams in an area to locate those having potential for improvement constitutes the first step in an orderly management sequence. Examination of streams should proceed on an individual basis and take into account the characteristics of the entire stream course, and not just those sections obviously in need of management. In this way many problems can be avoided, such as construction of pools over the only adequate deposits of spawning gravel in the stream. Diagnosis of specific problems in the stream leads to a prescription of treatment methods and their sequence. Implement first those treatments which have the greatest positive effect for the least expenditure of money and effort. A logical concluding step, but one that may be overlooked, consists of following treatment with an orderly program of inspection and maintenance (White and Brynildson 1967).

Do not fail to consider either the fertility of the water or the year-round carrying capacity of a stream which otherwise appears to have potential for improvement. Habitat manipulation aimed at increasing cover in a stream will prove of little value in providing more trout either if production is limited by a lack of nutrients or if the carrying capacity of the stream is drastically reduced at some season, as by freezing in winter or flooding in spring, thereby negating any effects of increased summer production (White and Brynildson 1967).

Protecting natural stream habitat best guarantees the perpetuation of native trout populations. The most significant habitat in small to moderate-sized streams consists of undercut banks, which in turn depend on extensive vegetative cover of the exposed bank (Wesche 1973). Livestock overgrazing presents the greatest threat to the integrity of headwater stream habitat quality in the West. Grazing livestock may destroy the vegetative cover and cave in overhanging banks, thereby eliminating the most important trout habitat. Loss of streambank vegetation leads to increased water temperatures, erosion and silting, elimination of spawning sites and reduction of food supplies in the stream, all of which drastically degrade trout habitat.

Guidelines have been developed to minimize damage to streams from logging, road building and mining operations; if they are conscientiously followed, good trout populations can be maintained in watersheds subject to these uses. The major multiple-use problem yet to be adequately treated on National Resource Lands, however, is the impact of livestock grazing on aquatic habitat. This problem is particularly acute in arid regions, where livestock often tend to concentrate in riparian vegetation along stream banks. Their impact on trout habitat can be devastating.

Although lack of riparian vegetation, caved-in banks, erosion, and siltation are readily visible results of overgrazing, quantitative data documenting such damage are not abundant. Gunderson (1968) reported on the fish popula-

tions in comparable grazed and ungrazed sections of Rock Creek, Montana. In 1964, 126.6 kg/ha of wild brown trout occurred in the grazed section and 167.8 kg/ha in the ungrazed section. Trout above 30 cm in length were more than three times as abundant in the ungrazed section. The major habitat differences between the grazed and the ungrazed sections concerned riparian vegetation, bank stability and average stream channel depth. The grazed segment of the stream consisted of a spread-out channel with mainly shallow riffle areas; it lacked deep pools and undercut banks. By 1970 the differences between the two stream segments were even greater. Biomass of wild brown trout had declined to 71 kg/ha in the grazed section, while it increased in the ungrazed part of the study area to 238.9 kg/ha. Interestingly, investigators found more mountain whitefish (Prosopium williamsoni) in the grazed than in the ungrazed section. The mountain whitefish, often accused of being a serious competitor with trout, more likely is just better adapted than trout to utilize disturbed habitat. In the natural, ungrazed section of the stream, whitefish comprised only 10 percent of the total fish biomass, whereas in the altered grazed habitat they made up 35 percent of the total fish biomass (Marcuson 1970).

The need for more precise data on the relationships of livestock density and grazing techniques to soil, climate, vegetation and impacts on stream environments and fish populations must be considered as the highest research priority to provide a sound basis for management decisions which will resolve the conflicts between livestock grazing and fish habitat quality.

The Intermountain Forest and Range Experiment Station of the U. S. Forest Service at Boise, Idaho has initiated a 10-year study titled "The effects of livestock grazing in high mountain meadows on aquatic environments, streamside environments and fisheries," under the direction of Dr. William Platts, who has studied livestock impacts on streams for many years. In an earlier report[2/] he raised significant questions on the efficacy of rest-rotation grazing management for restoring streambank vegetation and rehabilitating unstable banks. Platts observed that, while one year of rest may be sufficient to restore pasture grass, it may not be sufficient time to enable previously overgrazed streambank shrubs to recover.

[2/] Platts, W. and C. Roundtree. 1972. Bear Valley Creek, Idaho. Aquatic environment and fishery study. USDA Forest Service, unpubl. rept. 46 p.

Dr. Platts' research should provide a factual basis for multiple use management and more harmonious coexistence of livestock and trout populations. It would be a mistake, however, to delay attempts to reverse stream habitat deterioration 10 years while awaiting the outcome of the study. As a starting point, a recommendation in the Bureau of Land Management's environmental impact statement on grazing in Nevada (USDI Bureau of Land Management 1974) should be implemented, namely that costs for protecting critical environments, such as streams and riparian vegetation, be assumed by the interests causing the damage. If a rare trout restoration program is to be successful where the habitat is exposed to grazing, an integral part of the program must consist of strict grazing controls and watershed protection.

For background information on the actual or potential impact of various land-use practices on trout streams, see: Burns 1970, Cordone 1956, Cordone and Kelley 1960, Elser 1968, Megahan and Kidd 1972, Mullan 1975, Platts 1974, U.S. Forest Service 1975, White 1975, Gibbons and Salo 1973, and Grove 1976.

The U. S. Forest Service, Region VI, Portland, Oregon, is currently developing a fish habitat management policy which will include guidelines on:

I. Fish habitat protection and restoration
   A. Timber management and road construction
   B. Livestock grazing
   C. Mining
II. Fish habitat enhancement

The section on timber management and road construction has been completed. The section on livestock grazing is in draft form, scheduled for completion by July 1976. Other sections have not yet been started. The Oregon chapter of the American Fisheries Society passed a resolution endorsing this habitat management policy and urging its adoption on a nationwide basis (American Fisheries Society Newsletter, March-April, 1975).

POTENTIAL ROLE OF NATIVE TROUT IN FISHERIES MANAGEMENT

At first glance, the idea of promoting angling for a rare trout while the goal of the program is to increase its abundance may appear contradictory. Actually, though, the major hope for increasing the abundance of a rare trout lies in re-establishing it in waters, within its native range, where it has been extirpated or hybridized. In all likeli-

hood, such sites are now public fishing waters. State game and fish agencies funded by angler license fees may be understandably reluctant to close public fishing waters in order to re-establish a native trout population which would be fully protected from angling. No rare or endangered trout has become so through overfishing; the fear that fishermen might exterminate a population is simply not based in fact. Properly publicized, native trout can be used in unique, quality fisheries with virtually no expense, if populations reproduce naturally. Fishermen often place a higher recreational value on the opportunity to fish for a native trout than for a hatchery trout.

Special regulations for native cutthroat in Idaho test streams include a catch-and-release fishery and a 33-cm minimum size limit. The abundance, average size and catch-per-hour of trout in the stream have all increased under these regulations (Ball 1971, Bjornn and Thurow 1974, Hogander et al 1974). The National Park Service initiated a catch-and-release fishery on the Yellowstone River in Yellowstone National Park in 1973 after comparisons had shown that 309 cutthroat trout sampled in a closed section averaged 44.7 cm, against 36.1 cm for 378 trout from the open-fishing area. The catch-per-hour under the special regulations increased by two- to four-fold over the previous four years; most fishermen were enthusiastic over the change (Jack Dean, personal communication to Robert Behnke).

The research of Dr. Ted Bjornn, leader of the Idaho Cooperative Fishery Unit, has provided the best evidence of the potential of native cutthroat trout to produce a high quality fishery under special regulations. In 1971 investigators attempted to restore the abundance of the native trout in several miles of the upper St. Joe River, Idaho, by cessation of hatchery rainbow trout stocking and institution of an artificial lure fishery with a minimum size limit of 33 cm. Studies from 1968 to 1970 had revealed that the cutthroat was suffering heavy angling exploitation. Cutthroat trout caught by fishermen averaged only slightly over 17.8 cm; only 2.5 percent of the population exceeded 25 cm and only 0.1 percent exceeded 33 cm. The results of this management program have proved very encouraging. Rainbow trout have virtually disappeared from the unstocked area. Cutthroat trout increased from three- to six-fold in abundance in areas under special regulation, and without stocking. Average size of fish caught by anglers increased 5 cm in the first two years. The proportion of fish longer than 25 cm increased by 1000 percent; those over 33 cm increased by 3000 percent. The number of cutthroat caught increased by over four times--8100 after institution of special regulations versus 1800 before--and the catch-per-man-hour increased by six times, from 0.8 to 4.8, when comparing data of 1973 with that of 1968 in one five-mile stream section (Bjornn 1975). With the 33-cm minimum size limit, anglers kept many fewer cutthroat, but because of the greatly increased average size, the total weight of cutthroat trout creeled has probably not changed greatly. Angler response to the native cutthroat fishery has generally been quite supportive and by 1974, the stream enjoyed the same intensity of use that it had prior to the institution of special regulations, when heavy stocking of catchable rainbow trout supported the fishery. And so by protection from excessive exploitation, a more valuable fishery based solely on natural reproduction of a native trout has replaced a more expensive catchable trout fishery and the vulnerability of the cutthroat trout to repeated catching has resulted in a greatly increased catch rate.

Basically, the design of a special regulations fishery assumes that a natural trout population will undergo a "stockpiling" effect if smaller trout are protected from fishing exploitation and allowed to survive to a larger size. Most detailed studies of wild trout populations in streams have shown that special regulations designed to produce more and larger trout by restricting the catch do not work (Allen 1951; Hunt 1966, 1970; Latta 1973; Klein 1974). But most of these studies concerned brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). In these species, the lack of response to restricted catch results from the fact that habitat characteristics and food supply govern natural mortality rates and age-size structure of the populations. Typically, the above studies demonstrated that the overwhelming majority of production and biomass--from 70 to 90 percent--remained tied up in the 0 and I age groups (trout of sub-catchable size) and that about 98 percent of all trout hatched died from natural causes before they reached catchable size, typically in age group II+. Under circumstances where all age groups compete for a common food supply, and where sub-catchable trout constitute the bulk of the biomass, attempts to change the age and size structure of the population either by protecting it from angling or conversely, to promote angling in the hopes of stimulating growth in the fishes that remain, will have little effect on the population as a whole. This is because such a small segment of the total population is exposed to removal by angling, and because mortality is compensatory. That is, reduced angling mortality results in increased natural mortality; therefore the annual survival rate of trout of any year class remains approximately

the same whether the fish are protected or unprotected from angling.

Why, then, have the cutthroat trout populations mentioned above apparently responded to special protective regulations and exhibited a "stockpiling" effect? Three major factors are likely involved.

1. In all of these areas investigators speculate, but have not conclusively demonstrated, that the spawning and rearing areas exist apart from the main fishing areas. This reduces or eliminates the intraspecific competition between the younger, sub-catchable age groups, and the older, larger trout.

2. The vulnerability of the cutthroat trout to angling results in a higher catch-per-man-hour from cutthroat trout than from other species. No one knows how many times a trout might be caught and released in any given fishery, but Webster and Little (1947) reported that 200 rainbow trout stocked in an enclosed section of stream yielded a catch (when released) of 601 in 54 days--each trout was caught an average of three times. All studies to date have revealed virtually no (under five percent) mortality in trout released from artificial flies and lures.

3. In the studies on brook trout cited above, virtually no trout survived to age class IV or V. In most cutthroat trout populations, maximum ages of VI or VII appear rather commonly. Subsequent survival of older age groups results in a higher ratio of catchable-size to smaller sizes in cutthroat trout populations when compared to populations of typically short-lived brook trout.

A higher annual survival of older age groups (age II and older) indicates a decrease in natural mortality. Where angling mortality becomes high in such a situation, it may exceed natural mortality and depress the population below the carrying capacity of the environment. Temporary protection from angling, or a lowering of the creel limit in such instances, would result in higher annual survival and an increase in numbers.

Stream modification to produce more shelter and deeper water can increase the proportion of older to younger trout, food utilization, biomass and angler catch. Hunt (1969) demonstrated the efficacy of stream modification in Lawrence Creek, Wisconsin.

Generally, special regulations work best for a trophy fishery and require moderate to large rivers or lakes where food and space permit rapid growth and attainment of a large size. Virtually all fish in a small stream may die of old age before reaching a length of 25 cm. Most streams holding pure populations of rare, native trout are too small and remote from civilization to attract more than negligible fishing pressure; special angling restrictions are not justified under such circumstances. The Province of Alberta, Canada, has instituted management regulations for small streams containing cutthroat trout which consists of closing the streams in alternate years to allow a buildup of larger trout (Radford 1975).

SUMMARY

Steps in a native trout management program may consist of:

1. Survey of waters to collect specimens from suspected pure populations and to locate potential sites for re-introduction.

2. Taxonomic study of collections to identify pure populations.

3. Protection and possible improvement of habitat.

4. Introduction into barren or chemically treated waters isolated by some barrier against contamination by non-native trouts.

5. Establishment of special regulation fisheries where applicable.

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COLORADO RIVER CUTTHROAT
Salmo clarki pleuriticus

TYPICAL MERISTIC CHARACTERS

Scale counts	
lateral series (two rows above lateral line)	170-200+
and above lateral line (origin of dorsal fin to lateral line)	38-48
Vertebrae	60-63 (mean 61-62)
Gillrakers	17-21
Pyloric caecae	25-45 (mean 30-40)
Basibranchial teeth	1-20

[Taxonomic data from Behnke (1974, 1975), Wernsman (1973)]

SPECIES DESCRIPTION

No meristic characters unique to *S. c. pleuriticus* exist which can serve to authoritatively assign a specimen to this taxon. Hybridization resulting from the introduction of rainbow trout and other subspecies of cutthroat trout into the Colorado River basin further complicates the recognition of pure populations. In general, the mean values of at least ten specimens are needed to determine the degree of purity of a population in question.

Salmo clarki pleuriticus, native to the upper Colorado River basin is, with the greenback trout of the Arkansas and South Platte drainages on the other side of the Continental Divide, among the most colorful of all the recognized forms of cutthroat trout. The highly variable coloration consists typically of a poorly defined pink or red band along the brassy yellow sides. The ventral region may be suffused with crimson in mature males.

Character variability between populations of differing geographical areas exists due to long physical isolation of major habitat areas in the Colorado and Green River basins. For example, cutthroat trouts native to the upper Green River basin (La Barge Creek, north) display small to moderate-sized spots, typically smaller than the pupil of the eye, concentrated mainly on the caudal peduncle and, anteriorly, above the lateral line. Significantly larger spots occur on cutthroats from the Little Snake River drainage (a tributary to the Yampa River); these may approach a size more typical of the greenback trout. All degrees of intermediacy in spotting occur, but one should expect pure or essentially pure populations to share a high degree of uniformity within any geographical area where they have had the opportunity to freely intercommunicate. Baxter and Simon (1970) and Baxter (1972) present photographs of the large-spotted form of the Colorado River cutthroat, probably taken of specimens from the Little Snake River drainage of Wyoming. The illustration in this report is based on a specimen from Rock Creek, Wyoming,

Map 1. Indigenous distribution of Salmo clarki pleuriticus.

and characterizes the spotting pattern of the native trout of the upper Green River system.

DISTRIBUTION

The original distribution of *S. c. pleuriticus* extended from the headwaters of the Colorado River basin downstream to the Dirty Devil River, Utah, on the west and to the San Juan drainage of Colorado, New Mexico and Arizona on the east. But due to the warmth and turbidity of the water, most areas of the Colorado and Green Rivers did not comprise trout habitat until after the construction of mainstream dams (Behnke 1974, Wernsman 1973). Resultant isolation of the various major tributaries caused much of the variability inherent in *S. c. pleuriticus*.

Only two populations of the many examined appear to be wholly pure. They occur in an isolated section of Rock Creek, tributary to La Barge Creek, and in North Beaver Creek, an isolated tributary in the Piney Creek drainage; both populations exist in Sublette County, Wyoming. A possibly pure population discovered in 1970 and described by Wernsman (1973) from the very headwaters of the Colorado River in Rocky Mountain National Park can probably now be considered extinct for all practical purposes. Extensive sampling of the area in 1974 and 1975 turned up only three cutthroat trout in a multitude of brook trout.

Numerous populations, however, remain phenotypically good representatives of *S. c. pleuriticus* even though they show some evidence of hybridization. Although coloration and spotting patterns remain typical, closer examination reveals a slight hybrid influence in the form of the absence of basibranchial teeth, a greater range of variability in meristic characters, and a shift in the mean values of some characters. Such populations, while not wholly pure, still merit special recognition in management and land use decisions affecting their well-being (Behnke 1974, 1975, 1976; Wernsman 1973).

STATUS AND POPULATION TREND

Although cutthroat trout exist in good numbers in small lakes and streams in the Colorado River basin of Colorado, Utah, and Wyoming, pure populations of *S. c. pleuriticus* are indeed rare throughout its range.

Habitat alteration and the introduction of non-native trouts have caused the precipitous decline of the Colorado River cutthroat. Brown trout and rainbow trout have completely replaced *S. c. pleuriticus* in larger rivers, and brook trout have frequently displaced it in smaller tributaries, but the major factor pushing pure populations of the Colorado River cutthroat towards extinction has been hybridization with rainbow trout and non-native cutthroat trout used in stocking programs in Colorado, Utah, and Wyoming.

Miller (1972) included *S. c. pleuriticus* in his list of threatened freshwater fishes of the United States. The Utah Fish Committee of the American Fisheries Society's Bonneville Chapter lists it as endangered (Holden et al. 1974). The Colorado Division of Wildlife lists *S. c. pleuriticus* as threatened.

We recommend that *S. c. pleuriticus* be recognized as threatened by the U.S. Department of Interior.

LIFE HISTORY

No published life history data exist for this trout save that concerning the lacustrine-specialized and slightly hybridized population of Trapper's Lake, Colorado (Snyder and Tanner 1960, Drummond 1966), which has little value in relation to knowledge of the life history and ecology of *S. c. pleuriticus* throughout its range. All of the general information concerning life history and ecology appearing in Chapter I can be applied to *S. c. pleuriticus*.

A significant attribute of the Colorado River cutthroat in the Green River drainage of Wyoming lies in the fact that several "good" representative populations of this subspecies exist in several badly degraded streams of the foothills region. Many of these streams might be characterized as submarginal trout habitat, since they have suffered from the effects of overgrazing and irrigation dewatering, which have led in turn to erosion, warm temperatures and turbidity. In spite of habitat degradation and the introduction of rainbow trout and non-native forms of cutthroat trout, the native populations have resisted hybridization and displacement to a surprising degree. The only explanation appears to be that these local populations are hardy and adapted to the present conditions to such an extent that natural selection strongly favors maintenance of the native genotype. These factors--environmental degradation and the introduction of non-native

trouts--under which many predominantly S. c. pleuriticus still survive, have almost invariably caused the extermination of other subspecies of interior cutthroat trout (Behnke 1975).

HABITAT REQUIREMENTS AND LIMITING FACTORS

All western trouts of the genus Salmo possess essentially similar habitat requirements. A broad-based ecological variability allows populations to thrive in small streams, large rivers or lakes. While several lakes in the Colorado River basin originally contained S. c. pleuriticus whose basic life history attributes may have differed slightly from stream or river populations, the basic requirements in terms of temperature, oxygen, and substrate for reproduction and survival are quite similar for all S. c. pleuriticus. Any factors leading to loss of cover, siltation and warming of the waters will have detrimental impacts on cutthroat trout. But the most significant factor limiting the perpetuation of pure populations remains the hybridization resulting from the introduction of rainbow trout and exotic subspecies of cutthroat trout.

PROTECTIVE MEASURES

The Wyoming Game and Fish Department has hired a habitat management biologist, Dr. Allen Binns, to direct protection, enhancement and restoration of native trout populations in Wyoming. The Department is conducting several projects in the Green River drainage, some in cooperation with the Bureau of Land Management and the U. S. Forest Service. Projects include stream improvement, spawning enhancement, barrier construction, transplanting and experimental propagation. Dr. Binns reported on this work at the Colorado-Wyoming Chapter of the American Fisheries Society meeting in April 1975. Robert Behnke has examined several hundred specimens and has evaluated the relative purity of many samples of Green River basin cutthroat trout, collected during surveys made by Wyoming personnel (Behnke 1975).

The Bureau of Land Management, Colorado State Office, has fenced a section of Northwater Creek, a tributary to Parachute Creek in the oil shale country of northwest Colorado, to protect a good representative population of S. c. pleuriticus from livestock overgrazing. Another virtually pure population of S. c. pleuriticus occurs in Cunningham Creek, which has been affected by diversions from the Frying Pan-Arkansas Project of the Bureau of Reclamation. A cooperative agreement between the Colorado Division of Wildlife and the Bureau of Reclamation is designed to mitigate the dewatering impact of the project on the trout population.

Another Bureau of Reclamation project, the Meek's Cabin Reservoir in the Utah-Wyoming border area, flooded a natural barrier on the Little West Fork of the Black Fork River and an artificial barrier was constructed to prevent hybridization of the essentially pure S. c. pleuriticus population with rainbow trout.

According to 1973 and 1974 annual reports on fisheries management in Rocky Mountain National Park, prepared by James Mullan of the U. S. Fish and Wildlife Service, Vernal, Utah, plans exist for reintroduction of S. c. pleuriticus into the Colorado River drainage in the Park.

RECOMMENDATIONS

Although the original range of S. c. pleuriticus covers a large area in Wyoming, Utah, Colorado and New Mexico, only in the Green River basin of Wyoming has a concerted effort been made to survey waters for native trout populations, evaluate their relative purity and institute protective and restorative measures. The efforts of the Wyoming Fish and Game Department should be emulated in Colorado, Utah and New Mexico in order to authoritatively determine its status and to develop programs to protect and perpetuate this trout throughout its range.

Populations which are virtually pure and judged to be good taxonomic representatives should be given special recognition in relation to habitat protection or enhancement projects.

Habitat improvement and transplants into barren or chemically treated streams and lakes can effect the increased abundance of pure populations. Habitat managers should consider special regulation fisheries programs both to offer anglers the opportunity to fish for a rare and beautiful native trout and to generate interest and support among the public for restoration programs.

These recommendations assume added significance in view of the fact that S. c. pleuriticus is native to all of the oil shale region and much of the potential coal strip mine areas of Colorado, Utah and Wyoming. A 1975 report prepared for the Office of Biological Services of the U. S. Fish and Wildlife Service (Thorne Ecological Institute, 1975), gave the highest research priority to threatened and endangered species.

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Map 2. Indigenous distribution of Salmo clarki stomias.

GREENBACK CUTTHROAT
Salmo clarki stomias

TYPICAL MERISTIC CHARACTERS

Scale counts lateral series (two rows above lateral line)	175-220+ (mean values 185-216)
and above lateral line (origin of dorsal fin to lateral line)	42-60 (mean values 45-55)
Vertebrae	59-63 (mean values 60-62)
Pyloric caecae	24-46 (mean values 29-35)
Basibranchial teeth	Present, but highly variable

/ Taxonomic data from Behnke (1973, 1976), Wernsman (1973) /

SPECIES DESCRIPTION

Taxonomic criteria for *S. c. stomias* remain tentative due to the extreme rareness of pure populations and to the scarcity of ancient museum specimens. Even so, scale counts made from available specimens consistently exhibit the highest values of any cutthroat trout, or any trout in the genus *Salmo*. It may be assumed that extremely high scale counts are characteristic of pure populations of *S. c. stomias*, with some suggestion that those populations native to the South Platte basin may show slightly higher counts than those native to the Arkansas drainage. The greenback cutthroat displays typically lower numbers of pyloric caecae and vertebrae than most other subspecies of *S. clarki*, but much overlap occurs in these characters.

Salmo clarki stomias undoubtedly derived via an ancient headwater transfer from waters of the Colorado River basin to the South Platte River drainage, and for this reason shares many similarities with the Colorado River cutthroat, *S. c. pleuriticus*. The striking spotting pattern and intense coloration which can develop in mature fish is the most diagnostic field character of the greenback trout. *S. c. stomias* typically displays the largest and most pronounced spots of any cutthroat trout. Round to oblong in shape, they appear concentrated posteriorly on the caudal peduncle area. Coloration, similar to *S. c. pleuriticus*, tends toward blood-red over the lower sides and ventral region, especially in

mature males. Although a genetic basis exists to express characteristic color patterns, the actual manifestation of color intensity and pattern depends also on age, sex and diet. For example, a lake environment with crustaceans available for food will induce a more intense expression of color than a small stream environment.

DISTRIBUTION

The original distribution of S. c. stomias included the headwaters of the South Platt and Arkansas River basins in Colorado and a small area in southeastern Wyoming, but permanent trout habitat did not extend much beyond the foothills region. The advent of white man's civilization rapidly pushed the greenback trout back to headwater areas, replacing it in the larger streams with brown trout, and with brook trout in smaller tributaries. Further introductions into headwater streams and lakes displaced or hybridized the native greenback trout to the point of virtual extinction.

STATUS AND POPULATION TREND

When the white man came to Colorado, the greenback trout was the only game fish found in the Arkansas and South Platte river systems of the state. Rapid development brought about irrigation diversions and stream dewatering, mining pollution, logging, grazing, widespread introduction of non-native trouts, and caused a precipitous decline of native trout populations. Greene (1937) believed they were extinct. Although cutthroat trout remain common in high elevation lakes and streams of the South Platte and Arkansas River basins, virtually none of the populations so far examined resemble the native greenback trout (Wernsman 1973) but instead have resulted from introductions of various non-native races and crosses of cutthroat trout, usually with traces of rainbow trout hybridization. This circumstantial evidence suggests that the greenback trout may be the most vulnerable of all the western trouts to extinction.

Analysis of all specimens examined to 1970 suggested only two pure populations. One of these occurs in Como Creek, an isolated tributary to North Boulder Creek, Boulder County, Colorado; the other is found in the very headwaters of the South Poudre River above a barrier falls in Larimer County, Colorado. Due to its extreme rareness, S. c. stomias has been listed as endangered by the U. S. Department of the Interior.

A more complete discussion on the status of the green back cutthroat was written by Behnke (1976).

LIFE HISTORY

Little specific life history data exist for the greenback cutthroat. While S. c. stomias appears to lack the resiliency and adaptability which it needs to coexist with introduced trouts, the mechanisms by which it is displaced in relation to spawning behavior, temperature, habitat and food preferences, or other factors, remain unknown.

Some life history data have been collected on two slightly hybridized populations which can be considered "good" representative greenback trout populations. Bulkley (1959) gathered information on age and growth, food habits and movement of the greenback population in the headwaters of the Big Thompson River in Forest Canyon of Rocky Mountain National Park. Nelson (1972) studied the unexploited population of Island Lake, a reservoir in the City of Boulder watershed, and provided data on age, growth and fecundity. Jordan (1891) and Juday (1907) made observations on size and food habits of greenback trout in Twin Lakes, Colorado. None of these reports indicate any unique life history attributes of S. c. stomias. That is, the data and observations are typical of any trout living under similar circumstances and offer little insight into whatever subtle differences in ecology exist for the greenback trout which make it so vulnerable to displacement and extinction.

Early literature (Jordan 1891, Juday 1907, Hallock 1877, Anon. 1878, Land 1913) indicates that S. c. stomias was originally abundant but not noted for its large size. It reached a maximum weight of about 2.3 kg; other subspecies of cutthroat trout were known to attain weights of 4.5 to 9 kg or more.

HABITAT REQUIREMENTS AND LIMITING FACTORS

While no factual evidence exists to specifically define greenback trout habitat requirements and limiting factors, circumstantial evidence suggests that all of those factors relating to habitat alteration and introduction of non-native trouts which have caused declines in other native interior trouts, have had a particularly debilitating effect on S. c. stomias. The most obvious factor preventing successful restoration of the greenback trout into its original habitat is the presence of non-native trouts. Certainly reintroduction programs for greenback trout cannot achieve success unless the proposed site is completely barren of all non-native trouts and thoroughly protected from re-invasion.

PROTECTIVE MEASURES

The U. S. Department of the Interior officially recognizes S. c. stomias as an endangered species.

In a cooperative venture undertaken by the U. S. Forest Service, the Colorado Cooperative Fishery Unit and the Colorado Division of Wildlife in 1967, construction of a fish barrier and elimination of the brook trout population above it created a sanctuary for the greenback trout in upper Black Hollow Creek, a tributary to the Poudre River in Larimer County, Colorado. A self-reproducing population of greenback trout was established by introducing adult greenbacks from Como Creek (Gagnon 1973). But in 1973, Dale Wills, U. S. Forest Service (personal communication to Robert Behnke), found two brook trout above the barrier. A survey conducted in August, 1975 by Rolf Nitman, Colorado Division of Wildlife, found the brook trout now to be the dominant trout in the creek.

Restoration efforts on a larger scale took place in October 1973 when brook trout were eliminated with antimycin above a natural barrier in Hidden Valley Creek, Rocky Mountain National Park. Complete eradication of brook trout from this creek was made especially difficult due to the presence of about 15 acres of beaver ponds and associated backwaters (Mullan 1973). A sampling of Hidden Valley Creek on August 27, 1975 by James Mullan, U. S. Fish and Wildlife Service, and Dave Stevens, U. S. National Park Service, found no brook trout, and documented the presence of adults from the 1973 transplant as well as fish from natural reproduction in 1974 and 1975. But another transplant of Como Creek trout into a barren headwater section of the North Big Thompson River in Rocky Mountain National Park in 1971 failed, evidently because all the fish migrated downstream over a barrier during the winter months. A dense brook trout population below the barrier makes it doubtful that the greenback population will sustain itself there. In October 1975 the National Park Service treated Bear Lake with antimycin to eliminate the brook trout population, and on November 4 introduced greenback cutthroat taken from Como Creek.

Other transplant programs have used virtually pure greenback populations. A 1959 transplant in Rocky Mountain National Park took greenback trout from the headwaters of the Big Thompson River in Forest Canyon and stocked them into Fay Lakes in the park. The population did not establish itself there, but descendants of the original introduction have maintained a self-reproducing population in Caddis Lake, immediately below Fay Lakes, where James Mullan discovered them in 1972. Since 1971 the City of Boulder has granted permission to the Colorado Division of Wildlife to obtain spawn from a good representative greenback population in Island Lake and up to 100,000 eggs per year have been taken and propagated. The Division of Wildlife stocks these trout into several mountain lakes in northeastern Colorado as part of its fishery management program.

RECOMMENDATIONS

The greatest hope for expanding the distribution and abundance of S. c. stomias is by reintroducing it, within its native range, into suitable habitat barren of exotic trouts. Here, ironically, the 1973 Endangered Species Act actually hinders management of the greenback trout. While the intent of the Act is commendable, its prohibition of the "taking" or any form of harassment of an endangered species would mean closing to angling any stream into which greenback trout are introduced. Virtually all potential sites for greenback reintroduction are currently open to fishing. Public agencies are not enthusiastic to initiate restoration projects for an endangered trout which would result in closing public angling waters.

The simplest and most direct solution to this problem would be for the U. S. Department of the Interior to change the status of S. c. stomias from "endangered" to "threatened." A "threatened" status, while still affording protection under the Endangered Species Act, would not prohibit angling, thereby allowing this trout to be incorporated into fisheries management programs and encouraging the resumption of active restoration projects. This rare and beautiful trout has potential for inclusion in special regulation fisheries, which can stimulate public support for restoration programs, but first it must be removed from the endangered species list.

Well-organized surveys of isolated headwater areas of the South Platte and Arkansas River drainages could find and identify other pure or virtually pure greenback populations, as well as determine potential sites for reintroductions.

As with S. c. pleuriticus, it is not likely that many pure populations of S. c. stomias remain, but good representative populations, similar to those in Forest Canyon and Island Lake, should be identified for special recognition in relation to perpetuation and protection efforts.

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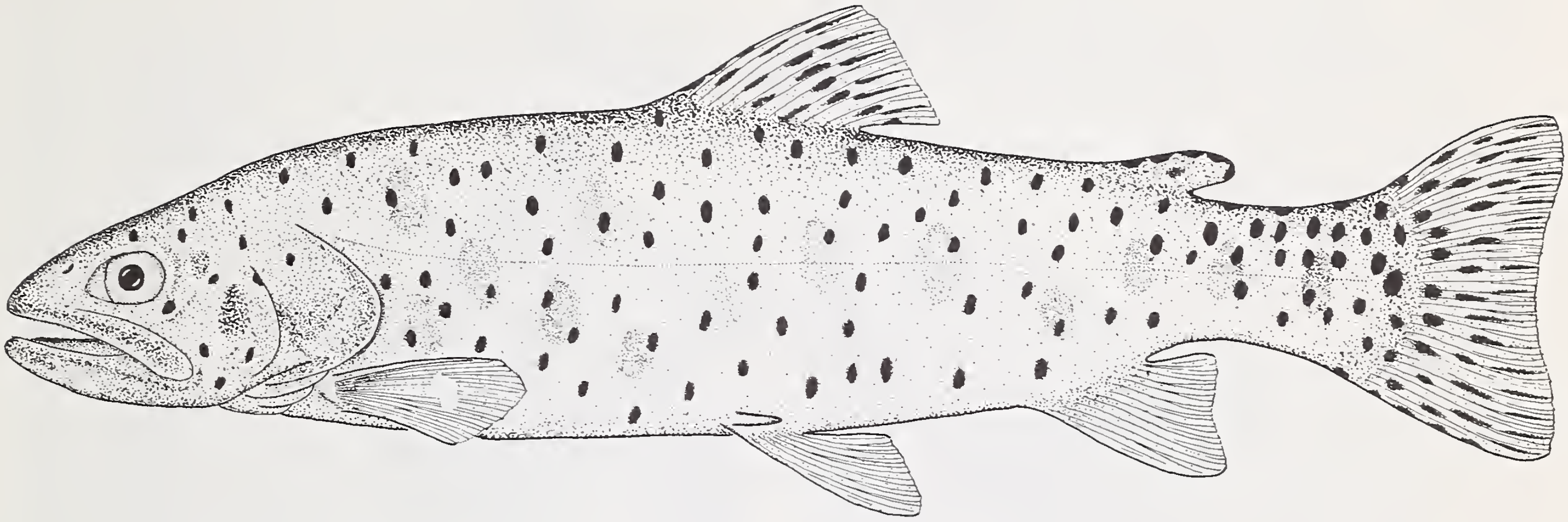


LAHONTAN CUTTHROAT
Salmo clarki henshawi

TYPICAL MERISTIC CHARACTERS

Scale counts	
lateral series (two rows above lateral line)	150-180 (125-150)[a]
and above lateral line (origin of dorsal fin to lateral line)	33-42
Vertebrae	61-63
Gillrakers	21-28 (19-23)[a]
Pyloric caecae	40-75+
Basibranchial teeth	Numerous and well developed

SPECIES DESCRIPTION

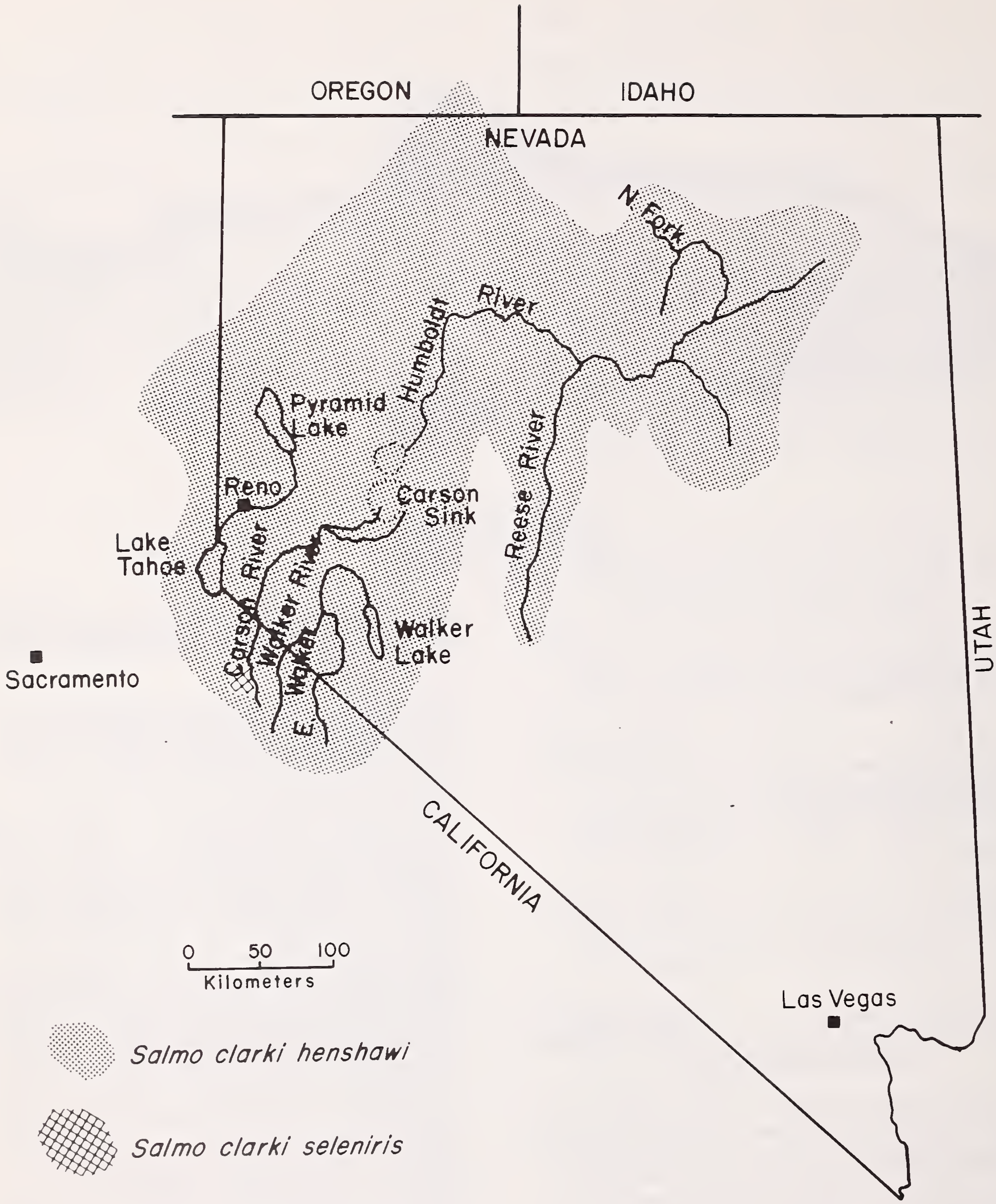
The Lahontan cutthroat trout achieved its great differentiation from all other subspecies of Salmo clarki due to its long physical isolation in the Lahontan basin with the resultant evolutionary selection for lacustrine specialization in pluvial Lake Lahontan, once the size of present-day Lake Erie. The number of gillrakers, higher than in any other western North American trout, further substantiates the ancient lacustrine evolutionary heritage of S. c. henshawi; with few exceptions, other taxa of trout possess only 17-21 gillrakers.

a Typical values of trout native to the Humboldt River system of Nevada.

The number of pyloric caecae is also higher in the Lahontan cutthroat than in other subspecies of S. clarki.

When Lake Lahontan desiccated 5000 to 8000 years ago, the separation of its major tributaries effectively isolated the fish fauna of the Carson, Walker, Truckee and Humboldt river systems from each other. One would expect a high degree of genetic variability among the populations of the different drainages under such circumstances, but in fact, all specimens examined from pure populations in the Truckee, Carson and Walker drainages conform to the diagnosis given above (Behnke 1960). However, the native cutthroat of the Humboldt River system of Nevada differentiates recognizably from cutthroats in the other tributaries to ancient Lake Lahontan. It displays fewer scales in the lateral series and a lower number of gillrakers. The Humboldt cutthroat trout may represent an undescribed subspecies which probably separated from S. c. henshawi much earlier than the final desiccation of Lake Lahontan, and probably differentiated in response to evolutionary stimuli to adapt to fluvial conditions in order to utilize the vast Humboldt River system (Behnke 1960, 1968, 1972b).

Jordan and Evermann (1898) described Salmo clarki tahoensis from Lake Tahoe under the assumption that two different cutthroat trouts, differentiated by size, inhabited Lake Tahoe. However, the type



Map 3. Indigenous distribution of Salmo clarki henshawi and Salmo clarki seleniris

specimen of *S. c. tahoensis* is identical to *S. c. henshawi* and the observed size difference probably resulted from the presence of both older fish which had repeatedly spawned, and younger fish spawning for the first time, in the spawning runs. Behnke (1960) considers *S. c. tahoensis* a synonym of *S. c. henshawi*. *Salmo evermanni*, a name also used to describe *S. c. henshawi*, was based on an introduced population of Lahontan cutthroats in the upper Santa Ana River, California (Benson and Behnke 1961). The trout named *Salmo regalis* from Lake Tahoe, and *S. smaragdus* from Pyramid Lake, are considered to be based on introduced rainbow trout, *S. gairdneri* (Behnke 1972c).

Thus, a primordial cutthroat invaded the Lahontan basin, probably from the Columbia River basin, and gave rise to a large lacustrine predatory fish, *S. c. henshawi*, from which an early separation led to the development of the cutthroat trout endemic to the Humboldt River drainage. Except for populations inhabiting Lake Tahoe, Pyramid Lake, Walker Lake and a few smaller lakes, the Lahontan cutthroat was forced to become a stream trout by the desiccation of Lake Lahontan. This ultimate division between lake and stream populations, with its associated evolutionary programming, did not result in taxonomic differentiation (except for that exhibited by the Humboldt cutthroat), but it is significant for subsequent discussions concerning life history, habitat, and the reasons for the catastrophic declines in abundance suffered by this trout.

The spotting pattern of the Lahontan cutthroat constitutes its most diagnostic field character. Large, roundish spots cover the body evenly and extend onto the head and often to the ventral surface. Other subspecies of interior cutthroat trout typically lack spots on the head and ventral region, and have spots more concentrated posteriorly on the caudal peduncle area. Coloration of the Lahontan cutthroat is dull when compared with that of the Colorado River cutthroat or the greenback trout. The crimson, gold and orange colors, if present at all, are much subdued.

DISTRIBUTION

The Lahontan cutthroat trout at one time occurred in abundance throughout the Lahontan Basin of California and Nevada, with major lacustrine populations in Pyramid Lake, Walker Lake, Independence Lake and Lake Tahoe, California, and Summit Lake, Nevada; fluvial populations occurred in the Carson, Walker and Truckee River systems of California and in the Humboldt drainage of Nevada.

Currently the only lakes which harbor pure stocks of *S. c. henshawi* are Summit Lake, Nevada, and Independence Lake, California. By 1959 the only other known populations conforming to the diagnosis of *S. c. henshawi* occurred in Dog Creek of the Walker River drainage of California, the very headwaters of the East Carson River above a falls, and one of its tributaries, Murray Canyon Creek (Behnke 1960). Behnke discovered a small, apparently pure population in Pole Creek, tributary to the Truckee River, in 1961, but ten years later extensive electro-fishing disclosed only brook trout, and the native cutthroat of Pole Creek is now presumed extinct. More recently, apparently pure *S. c. henshawi* populations have been discovered in Golden Canyon Creek (an East Carson River tributary), By-Day Creek and East Fork Desert Creek (in the Walker River drainage), and Macklin Creek (tributary to the Yuba River in the Sacramento River basin). The Macklin Creek population is probably the result of an early transplant from the Truckee River. A transplant from Macklin Creek into a barren, isolated section of East Fork Creek of the Yuba River drainage in 1970 and 1971 has established a small population there (California Department of Fish and Game, Threatened Trout Committee notes; Stephen Nicola, personal communication to R. Behnke).

Both California and Nevada annually propagate millions of "*S. c. henshawi*", but the great majority of these hatchery fish come from the Heenan Lake stock which originated from a transplant of *S. c. henshawi* from the Carson River--a fluvial, not a lacustrine population--into Blue Lake, California, in 1864. Two subsequent introductions of rainbow trout into Blue Lake resulted in hybridization before the establishment of the present stock in Heenan Lake. The Heenan Lake "cutthroat" bears a good phenotypic resemblance to *S. c. henshawi*, but the lower number of scales and gillrakers (Behnke 1960) and the makeup of its blood serum (Utter and Ridgway 1966) disclose the rainbow trout influence. Thus, the trout widely propagated as *S. c. henshawi* is in reality a counterfeit of the real thing, and the widespread introduction of the Heenan Lake stock in California and Nevada is not considered as part of the distribution of the true *S. c. henshawi*.

STATUS AND POPULATION TREND

Commercial fisheries harvested vast numbers of Lahontan cutthroat trout, famed for its abundance and size, from Pyramid Lake, Walker Lake and Lake Tahoe during the last half of the nineteenth century, supplying the needs of towns and mining camps in the area

and shipping surplus fish by Wells Fargo express to San Francisco and other cities. Robert Behnke, in a 1974 report prepared for the Paiute tribe's litigation over the water rights and fishery values of Pyramid Lake, conservatively estimated that the cutthroat trout of Pyramid Lake alone could have supported a fishery of 454,000 kg per year in the nineteenth century. And yet the famed Pyramid Lake cutthroat stock was allowed to become extinct in 1938 (Sumner 1940) despite the fact that it was the largest of all western trouts; the average size of fish caught in 1938 was nine kg (Sumner 1940), and even though the official record for this trout (and the world record cutthroat trout) was 18.6 kg, the Indian fishery at Pyramid Lake reported trout weighing up to 28 kg (Wheeler 1969).

Fish commission reports of Nevada and California and other early literature condemned rampant poaching, uncontrolled exploitation and damming, diversion and pollution of the rivers. But overfishing did not bring about the virtual demise of S. c. henshawi. Blockage of spawning tributaries decimated the lacustrine populations, and the introduction of non-native trouts into the streams of the Lahontan basin caused replacement or hybridization of the native cutthroat trout in the rivers.

It may seem strange that such a large trout, once so abundantly distributed throughout the great area of the Lahontan basin could so rapidly slide toward extinction. The populations inhabiting Pyramid, Tahoe and Walker Lakes were specialized to exist in a lacustrine habitat; they had adapted very highly to their environment. These stocks appeared greatly resistant to the effects of hybridization, perhaps through negative selection toward any hybrids produced. The original cutthroat trout of Pyramid Lake and Lake Tahoe maintained their stocks until the 1930's, despite massive stocking of rainbow trout into the lakes and tributaries since before 1890, and deliberate experimental hybridization in hatchery propagation (Behnke 1960). But in 1906, the Newlands Irrigation project constructed Derby Dam on the Truckee River, 30 miles above Pyramid Lake. Thus, the Pyramid Lake cutthroat trout were denied access to most of the spawning habitat of the Truckee River (Snyder 1917). Even so, these trout were to maintain their numbers until the 1920's, when diversion of the entire flow of the Truckee became more frequent, with consequent great losses of spawning trout. The last spawning run of trout in the Truckee River occurred in 1938 (Sumner 1940), but streamflow was insufficient for reproductive success and this magnificent race became extinct. In Lake Tahoe, damming, pollution and siltation of its tributaries resulted in the demise of the native cutthroat soon thereafter. The cutthroat trout of Walker Lake held on until 1948 when 16 large spawners were trapped near the mouth of the Walker River, which, due to irrigation diversions, no longer had flows sufficient for the reproductive requirements of the trout in the lake. The Nevada Department of Fish and Game removed spawn from these trout and began a brood stock; the present population of Walker Lake is maintained by hatchery propagation (Behnke 1960, Johnson 1974).

S. c. henshawi possessed an evolutionary heritage which made it highly adapted and successful in lake environments; it was much less suited for stream existence and quite vulnerable, in fluvial environments, to displacement by brook, brown and rainbow trouts and to hybridization with rainbow and non-native cutthroat trouts. Today only a very few streams shelter pure stocks of Lahontan cutthroat trout (see page 22).

The purity of the Walker Lake stock, propagated in Nevada, is in doubt. No ancient museum specimens exist for study of the original population, and ample opportunity for hybridization in the Walker River has existed for more than half a century. Indeed, specimens of the stock raised at Verdi, Nevada, have slightly lower gillraker counts and scale counts than is typical of pure S. c. henshawi (Behnke 1960). But the highly alkaline Walker Lake environment, lethal to all other trouts, probably exerted selective pressures strong enough to maintain the genotype of the Walker Lake cutthroat without significant modification from hybridization. The cutthroat trout of Walker Lake may play an increasingly significant role in propagation efforts involving a large, lacustrine predator. Cutthroat trouts of Walker and Independence Lakes are the only existing stocks that have historically coexisted with other elements of the native fish fauna of the Lahontan basin and as such might be expected to possess the genetic programming for maximizing effective coexistence with and utilization of this associated fauna in other lakes.

The native cutthroat trout of the Humboldt River drainage of the Lahontan Basin of Nevada has fared better than S. c. henshawi in the rest of the basin. This trout, evidently more specialized for stream life and apparently highly adapted to the harsh flood-drought cycle of this arid region, has persisted in many small streams despite repeated introductions of non-native trouts. Pure or essentially pure populations exist in about 20 streams

(R. J. Behnke, personal notes and data). The entire trout populations in some small streams may be restricted to a few small pools and beaver ponds in late summer, when the streams become intermittent. Although the undescribed subspecies of the Humboldt drainage persists in several localities, it cannot be considered as common or abundant, and merits the same considerations for protection and restoration as S. c. henshawi.

Bond (1961, 1966) listed S. c. henshawi as the native trout of the Alvord desiccating basin, which is contiguous with the northern Lahontan basin on the Oregon-Nevada border. Behnke (1960) recognized that there were two distinct groups of cutthroat trout in this basin (or basins), one in the Virgin Creek - Trout Creek drainage of the Alvord Lake sump and one in Willow and Whitehorse Creeks, which drain out onto the desert east of Alvord Lake at a higher elevation. At that time Behnke believed that the trout collected from Virgin Creek, which possessed 21-25 gillrakers, were probably introduced Lahontan cutthroat trout and that the Willow and Whitehorse Creek populations constituted an undescribed subspecies. Subsequent information and re-examination of the Virgin Creek specimens has caused Behnke to reject his previous belief that these specimens are S. c. henshawi. Though the Lahontan cutthroat may have gained access to Virgin Creek and the Alvord basin via an ancient connection with Summit Lake, the specimens are sufficiently dissimilar to be classified as a new subspecies (Behnke 1972b, 1973). The native trout of the Virgin Creek - Trout Creek drainage of the Alvord basin of Nevada and Oregon are presumed extinct, since no specimens have been collected since 1934. The characteristics of the cutthroat trout in Willow and Whitehorse Creeks are close to the Humboldt cutthroat of the Lahontan basin and their origin may have resulted from a headwater stream capture from the Humboldt system. Native trout still exist in Willow and Whitehorse Creeks but remain unclassified.

Due to the extreme rareness of pure S. c. henshawi, the U. S. Department of the Interior endowed it with the status of "endangered." But to facilitate management and restoration efforts, the status of the Lahontan cutthroat trout was changed from "endangered" to "threatened" (Federal Register 40(137), 16 July 1975). This action also avoided the problem of attempting to enforce the "no taking" provision of the Endangered Species Act of 1973 in the popular sport fishery at Pyramid Lake, where pure S. c. henshawi from Summit Lake, partially hybridized S. c. henshawi from the Heenan Lake stock and F_1 rainbow x cutthroat hybrids have all been stocked together to provide angling.

LIFE HISTORY

Snyder (1917) made many general observations relating to life history of Lahontan cutthroat trout, mainly the Pyramid Lake stock. Juday (1907) published some data on Lake Tahoe cutthroat. Calhoun (1944a, 1944b) described some life history attributes of the partially hybridized Heenan Lake trout in Blue Lake and Heenan Lake. Lea's (1968) M. A. thesis on the Independence Lake cutthroat contains the most comprehensive data on a pure population of S. c. henshawi.

All of the above studies were based on lacustrine stocks. The work of Calhoun (1944a), which points out the variability in growth, age at maturity, food habits and other life history factors between populations of the same stock (the Heenan Lake strain) living in Blue Lake and in Heenan Lake demonstrates that the specific details gained from any life history study must be restricted in application to the site of the studies. Broad generalizations applied to other populations might prove erroneous.

Based on all these studies, particularly that of Lea (1968), it may be assumed that in lakes, S. c. henshawi tends to feed more in the pelagic zones and on the surface. When available, fish become predominant in its diet when it reaches a size of about 30.5 cm. In Independence Lake, the redside shiner, kokanee salmon and Paiute sculpin were the main fish eaten.

The geologic history of the Lahontan basin and the distinctive characters of S. c. henshawi indicate that this trout has had the longest period of evolution of any western trout in which to specialize as a large predator in a lacustrine environment (Behnke 1972c).

The weak link in the life cycle of S. c. henshawi concerns its reproductive requirements; it is an obligatory stream spawner. The subspecies' superb adaptability to the Truckee River - Pyramid Lake system was negated by the blockage of access to spawning habitat in the Truckee River.

S. c. henshawi well illustrates certain ideas regarding intraspecific variability in ecological, physiological, and behavioral traits. The various stocks, isolated thousands of years ago by the desiccation of Lake Lahontan, were subjected to their own unique genetic programming under natural selection in different environments, and this was particularly true in lacustrine versus fluvial populations. Probably only the Pyramid Lake population of S. c. henshawi continuously

evolved in a large lake environment with a full range of the Lahontan basin fauna.

Interpretation of this evidence suggests that no existing trout classified as S. c. henshawi, introduced into Pyramid Lake, can be expected to duplicate the adaptive success and large size of the original Pyramid Lake S. c. henshawi, due to subtle differences in their life history characteristics. This interpretation is supported by the fact that in almost two decades of stocking "S. c. henshawi" into Pyramid Lake, the maximum size recorded has not reached the average size of the original stock recorded during its 1938 spawning run, and only reaches one-third to one-half the maximum size once attained by the now-extinct Pyramid Lake cutthroat (Behnke 1968, 1972a, 1972c; Trojnar and Behnke 1974).

HABITAT REQUIREMENTS AND LIMITING FACTORS

The lack of suitable stream spawning habitat has limited lacustrine populations of S. c. henshawi. Although hatchery propagation and stocking into lakes provide a means of avoiding this limiting factor, until brood stocks of S. c. henshawi are greatly expanded, the introduction of S. c. henshawi x S. gairdneri hybrids cannot be considered an authentic restoration of the Lahontan cutthroat.

Stream populations of Lahontan cutthroat have suffered from hybridization with rainbow trout, except in the Humboldt River basin. Many of the streams in which the Humboldt cutthroat occurs have a long history of stocking with rainbow trout, Yellowstone cutthroat, and brook and brown trout. The only reasonable explanation for the resistance of the Humboldt cutthroat to displacement and hybridization might be this trout's superior adaptation to its harsh environment.

A unique tolerance to high alkalinity levels, which can be attributed to a physiological adaptation to the environments of Lake Lahontan during its period of desiccation and increasing concentrations of dissolved solids, allows S. c. henshawi (or trout with a predominant S. c. henshawi genotype) to thrive in waters such as Walker Lake which are lethal to all other trouts (Johnson 1974). The mechanisms of "alkalinity toxicity" and precisely which ions are toxic to other trouts, yet tolerated by S. c. henshawi, remain unknown. But this unique adaptation to an environmental extreme by S. c. henshawi could prove useful in establishing fisheries in lakes where other trouts could not survive.

PROTECTIVE MEASURES

The Threatened Trout Committee of the California Department of Fish and Game has conducted surveys to find remnant populations of S. c. henshawi and to determine sites for establishment of new populations by transplants. A successful transplant of this subspecies from Macklin Creek to the barren headwaters of nearby East Fork Creek took place in 1970 and 1971. Propagation of Independence Lake cutthroat began primarily to maintain the stock in Independence Lake; 32,000 trout from eggs taken in 1974 were on hand in 1975. Of these, 5000 were marked and stocked in Heenan Lake to facilitate future propagation and 25,000 were restocked into Independence Lake (Threatened Trout Committee, California Department of Fish and Game minutes of meetings; Stephen Nicola, personal communication to Robert Behnke). Removal of the beaver dams which blocked the spawning run from Independence Lake in 1964 greatly increased the success of natural reproduction of this stock (Lea 1968).

The impact and potential threat to the Independence Lake cutthroat stock by the planned Walt Disney Productions resort to be built at Independence Lake, is difficult to forecast. The obvious threat of eutrophication exists, but more important might be a demand for stocking great numbers of trout to meet increased fishing pressure in Independence Lake. Hopefully, developers will recognize the uniqueness and value of the native Lahontan cutthroat of Independence Lake and design a propagation program and special regulation fishery based on this fish and perhaps kokanee salmon.

The U. S. Fish and Wildlife Service propagates the pure strain of S. c. henshawi in Summit Lake with the objective of restoring it in Pyramid Lake. The ultimate goal is to reestablish natural reproduction in the Truckee River, once adequate flows and fish passage facilities become a reality in the lower Truckee River (Gary Rankel, U. S. Fish and Wildlife Service, personal communication to Robert Behnke). But as noble as this goal may be, present conditions in the Truckee, particularly the potential for hybridization with the abundant rainbow trout population which exists there, indicates that its realization will be difficult if not impossible.

In recognition of the significance of the Mahogany Creek watershed, the only spawning tributary available to the Summit Lake cutthroat stock, the Bureau of Land Management removed the watershed from mining exploration to protect this stream from further degradation. But it failed to institute the grazing controls

which had been proposed, and consequent effects of overgrazing resulted in the need to remove silt buildup at the mouth of the stream each year to allow the spawning trout to enter the stream. The BLM cited the effects of livestock grazing on the Summit Lake cutthroat in its environmental impact statement on grazing in Nevada (Anonymous 1974) as an example of the problems of multiple-use management on public lands when livestock interests wield the predominant influence--despite national priorities regarding the survival of an endangered species.

In the Humboldt drainage, a successful transplant of the native trout from Frazer Creek to Sherman Creek, Elko County, Nevada has taken place, with future transplants anticipated. The new Sherman Creek population has been observed in water temperatures reaching 25.6° C., perhaps a record high temperature for cutthroat trout in natural conditions (Pat Coffin, Nevada Fish and Game Department, personal communication to Robert Behnke).

RECOMMENDATIONS

The importance of the Lahontan cutthroat trout both in propagation as a sport fish and for the role it plays in fisheries management dictates two goals for the management and restoration of this trout:

1. Identification, protection and transplants of pure population

2. Propagation of pure *S. c. henshawi* to replace the hybridized Heenan Lake strain for stocking in the Lahontan basin.

Some compromises might be encouraged in selection of stocks in order to create the best-adapted genotype for waters such as Pyramid Lake. The Summit Lake population, the major pure stock of *S. c. henshawi* available for propagation, has probably been isolated from all other fishes for several thousand years. Crossings of the Summit Lake trout with Independence Lake cutthroat and/or Walker Lake cutthroat might result in a broader base of herterozygosity and greater adaptability to new waters. Because virtually all introductions of hatchery-propagated *S. c. henshawi* occur in lakes where natural reproduction does not occur, no negative impact would be expected from experimental interracial hybridization in a restoration program for pure *S. c. henshawi*. Of course, the only trout stocked into Independence Lake, where natural reproduction does occur, should be from the native population.

One promising option of a propagation program should be tested and that concerns the propagation from parents surviving in the new environment to take advantage of natural selection favoring certain heriditary traits. For example, the stocking of Summit Lake cutthroat trout into Pyramid Lake is presently accomplished by an annual egg take at Summit Lake so that each generation in Pyramid Lake is derived directly from Summit Lake. A comparison should be made over several generations in relation to survival and contribution to the Pyramid Lake fishery, between fish propagated from eggs taken at Summit Lake and from eggs taken from Summit Lake trout surviving to maturity in Pyramid Lake. An item in the Sport Fishing Institute Bulletin (April, 1976) is of particular relevance in this respect. A race of Columbia River coho salmon stocked in the Lamprey River, New Hampshire, gave a total survival of adults returning to the home stream of 1.22 percent, but the F_1 generation resulting from eggs taken from the returning salmon yielded a total survival of 5.75 percent or a 4.7 fold increase in survival and also a 50 percent increase in average weight of surviving salmon.

The Walker Lake strain needs an evaluation of its relative purity. The Humboldt native cutthroat needs an established lake, similar to Heenan Lake, for its propagation. This trout possesses a good fisheries management potential, acquired during its recent evolution under the harsh climatic regime of northeastern Nevada. When it has gained access to reservoirs from its headwater strongholds during high runoff years, the Humboldt cutthroat has greatly exceeded hatchery trout in both growth and survival (Behnke 1968 and personal data).

A propagation program for *S. c. henshawi* and the Humboldt cutthroat should have as one of its goals that of demonstrating the practical values of preserving and utilizing the genetic diversity of rare and endangered trouts to again make these fish a dominant element in their native range.

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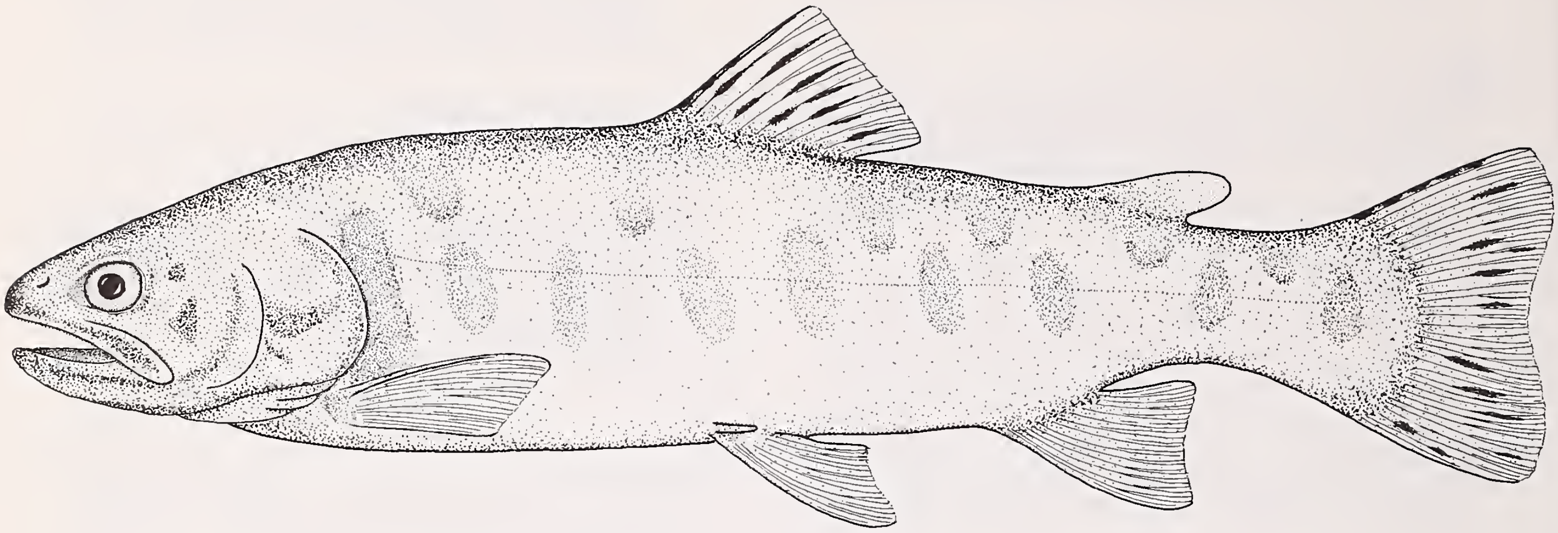

PAIUTE TROUT
Salmo clarki seleniris

TYPICAL MERISTIC CHARACTERS

Scale counts	
lateral series	
(two rows above lateral line)	150-180
and above lateral line (origin of dorsal fin to lateral line)	33-40
Vertebrae	60-63 (mean 61.8)
Gillrakers	21-27 (mean 24)
Pyloric caecae	50-70
Basibranchial teeth	2-15

(Behnke 1960, personal data from specimens taken from Silver King Creek, California, 1933-1956)

SPECIES DESCRIPTION

The Paiute (sometimes spelled Piute) trout was described by Snyder (1933) from above a barrier falls in the headwaters of Silver King Creek, Alpine County, California.

Silver King Creek is tributary to the East Fork of the Carson River of the Lahontan basin. Snyder recognized the affinities and derivation of the Paiute trout from S. c. henshawi, the trout native to the Lahontan basin. The absence of spots on the body seemed like such a striking diagnostic character to Snyder that he described "Salmo seleniris" as a new species and became somewhat poetical in his selection of a specific name which suggested "...a fanciful resemblance of its evanescent tints to the lunar rainbow" (Snyder 1934).

Snyder's publication, however, provided little data on the taxonomic characters of the Paiute trout, particularly concerning its range of variability and an adequate comparison with S. c. henshawi. No published taxonomic data has appeared since to supplement his original work, but a Master of Arts thesis by Behnke (1960) and subsequent data which he has accumulated reveals that S. c. seleniris has nearly identical values to S. c. henshawi in all of its meristic characters. Data on S. c. seleniris which appear above are published here for the first time.

The gillraker number indicates that the separation of S. c. seleniris in Silver King Creek from an ancestral S. c. henshawi occurred after S. c. henshawi had attained its ultimate number of gillrakers in pluvial Lake Lahontan under lacustrine selective pressures, no more than about 5,000 to 8,000 years ago. The Paiute trout, then, probably was not derived from the primordial trout which invaded the Lahontan basin, but developed instead rather recently, differing from S. c. henshawi only in spotting pattern. Most likely the phylogenetic separation of S. c. seleniris from S. c. henshawi in the Carson River drainage occurred after the isolation of the various stocks of S. c. henshawi in the Truckee,

Carson and Walker river systems by the desiccation of Lake Lahontan.

Even the absence of spots on the body as a character to differentiate *S. c. seleniris* from *S. c. henshawi* cannot be used as absolutely as originally believed. Stephen Nicola, California Department of Fish and Game, carefully examined 79 of the specimens of *S. c. seleniris* taken from Silver King Creek in 1933 and found that while 47 specimens had no spots, 32 had from one to nine spots on the body (S. Nicola, personal communication to R. Behnke, 5 June 1974).

DISTRIBUTION

When Snyder described the Paiute trout in 1933, he assumed that it had originated in Silver King Creek above Llewellyn Falls and was limited to the known distribution at that time. But Silver King Creek above Llewellyn Falls was originally barren of fish; it had been stocked by a sheepherder with trout taken from lower Silver King Creek in 1912. Another transplant above the falls took place in 1924. The subsequent discovery in 1946 of Paiute trout in Corral Valley and Coyote Valley, two isolated tributaries to lower Silver King Creek, was attributed to an early but unknown introduction by man, which may have occurred as early as the 1860's when Canadian loggers worked in the area (Baugh 1973). Stephen Nicola kindly provided to Robert Behnke the information on these transplants,which is filed in the office of the California Department of Fish and Game, Sacramento, and taken from statements made in 1944 by Mr. Virgil Connell, a stockman who pastured sheep in the Silver King watershed.

Mr. Connell's statements raise a question on the original distribution of Paiute trout. If the stream above Llewellyn Falls was devoid of trout prior to 1912, and if the introduced trout came from lower Silver King Creek, then the original range must have included the Silver King drainage above some natural barrier which prevented interbreeding with the typical Lahontan cutthroats of the East Carson River system.

By the time Snyder described *S. c. seleniris* in 1933, the trout below Llewellyn Falls had thoroughly hybridized with rainbow trout (Behnke 1960). It would be interesting to know the date of the first introduction of rainbow trout, and of Lahontan cutthroat trout, into the Silver King drainage.

The present known distribution of Paiute trout consists entirely of introduced populations which include those in Fly Valley and Four Mile Canyon Creeks (isolated tributaries to Silver King Creek); North Fork Cottonwood Creek and Cabin Creek, Mono County; Birchim Lake, Inyo County; and Delany Creek, Yosemite National Park, where the National Park Service is attempting to remove brook trout to sustain the Paiute population.

STATUS AND POPULATION TRENDS

Silver King Creek was closed to fishing above Llewellyn Falls in 1933, after *S. c. seleniris* was discovered there. But when angling restrictions were removed in 1952 it was found that Paiute trout, like most cutthroat trout living in streams, was easily caught and vulnerable to over-exploitation. But it was the apparently inadvertant stocking of 5000 rainbow trout above Llewellyn Falls by the California Department of Fish and Game in 1949 which dealt the final blow to the Paiute trout as a pure form in Silver King Creek. A common fishery management practice at that time was to "seed" headwater mountain streams with "new blood" in the form of hatchery trout fry, even though evidence had long accumulated to demonstrate the worthlessness of such stocking. After the 1949 rainbow trout stocking, Lahontan cutthroats were mistakenly dropped by airplane into Whitecliff Lake, which flows into Bull Creek and joins Silver King Creek just above Llewellyn Falls.

In 1957, investigators found hybrid fish with spots above Llewellyn Falls and by 1963 they considered the Silver King Creek population a hybrid swarm. Paiute trout populations in Corral and Coyote Valleys had by 1963 also thoroughly hybridized with rainbow trout from an unknown introduction; half the specimens lacked basibranchial teeth, and gillraker numbers ranged from 19-24, versus 21-27 in pure Paiute trout. These specimens also exhibited a profusion of spots on the body (R. Behnke, personal notes and data).

Fortunately, pure Paiute trout had been introduced and established into formerly barren Fly Valley, Four Mile Canyon and North Fork Cottonwood Creeks to ensure its perpetuation.

Treatment with rotenone in 1964 of Silver King Creek above Llewellyn Falls attempted to eliminate hybrids, and pure Paiute trout were re-introduced (McAfee 1966, Staley 1965). But some hybrids survived the poisoning because of extensive beaver pond areas which made thorough treatment difficult and by 1968 fish with spots on the body again occurred.

The Threatened Trout Committee of the California Department of Fish and Game, in light of the failure of chemical treatment in

Silver King Creek, has instituted an alternative management practice of annual electrofishing in the creek above Llewellyn Falls with selective removal of fish which display more than five spots on the body. The efficacy of this technique is currently being tested (Ryan and Nicola, 1976).

The U. S. Department of the Interior had officially listed S. c. seleniris as an endangered species, but because of management problems resulting from the "endangered" classification (see chapter on S. c. stomias, page 19), the California Department of Fish and Game petitioned the Interior Department to change the status to "threatened." The official change in status from "endangered" to "threatened" took place in July, 1975 (Federal Register 140 (37), 16 July 1975).

All present pure populations of self-reproducing Paiute trout occur in small, isolated environments, but the nucleus exists to intensify restoration projects.

LIFE HISTORY

Some life history information appears in McAfee (1966). Darrel Wong (1975) and James Diana (1975) present more detailed data based on studies of the North Cottonwood Creek population.

Paiute trout attain a length of only 23 to 25 cm in small streams such as the headwaters of Silver King Creek, but are known to reach lengths of up to 46 cm in larger bodies of water such as Birchim Lake (McAfee 1966).

The most significant life history attribute of the Paiute trout in relation to management must be implied from a knowledge of its evolutionary history. S. c. seleniris has been completely isolated from other species of fish for probably several thousand years, ever since its separation, in Silver King Creek, from a Lahontan cutthroat trout ancestor. The cutthroat in other areas of the Lahontan basin evolved with a diverse fauna of several species of minnows and suckers, a whitefish, and a sculpin. Selective pressures can differ greatly between populations coexisting with a diversity of species and those developing in isolation, with the result that life history and behavioral characteristics of isolated fishes may prevent them from coexisting successfully with other species. It must be assumed that a transplant of Paiute trout will stand a good chance of success only in waters barren of other fishes.

HABITAT REQUIREMENTS AND LIMITING FACTORS

Although the ancestral trout of the Lahontan basin lived as a large, lacustrine predator in pluvial Lake Lahontan, the Paiute trout has evolved in a small, cold stream environment. Since it thrives also in Birchim Lake, it can be expected that the Paiute trout can adapt successfully to virtually any suitable trout waters. The ultimate limiting factor, though, may be the presence of other fishes, particularly trouts.

Schneegas and Pister (1967) and Ashley (1970) have written habitat management plans for the Paiute trout.

PROTECTIVE MEASURES

To insure protection of the upper Silver King Creek watershed, the Toiyabe National Forest and the Sierra Pacific Power Company transacted a land exchange in 1971 which made most of the watershed public land. The U. S. Marine Corps agreed to discontinue its use of the watershed for survival training in 1963. After the poisoning of Silver King Creek to remove hybrids in 1964, pure Paiute trout were reintroduced. But hybrids reappeared and the California Department of Fish and Game is attempting to control them by annual electrofishing. The construction of a barrier on Four Mile Canyon Creek in 1972 will hopefully insure the isolation of Paiute trout there.

Transplant programs have established several new populations (see page 29).

The Threatened Trout Committee of the California Department of Fish and Game provides the structure to coordinate state and federal efforts to protect and enhance the distribution and abundance of this trout.

RECOMMENDATIONS

Pure populations of S. c. seleniris no longer exist in its native waters. The extremely limited natural distribution and catastrophic decline in abundance of such a fish may make it a matter of common sense not to restrict restoration efforts to the native range. Although California's Threatened Trout Committee has not yet formalized its thinking in this matter, the current view is that Silver King Creek and its tributaries down to a point below the confluence of

Corral Valley Creek and North Fork Cottonwood Creek will be the extent of its restoration efforts, although protection of Paiute trout in Cabin Creek and Birchim Lake will remain in force also (S. Nicola, personal communication to R. Behnke).

The Paiute trout could become an integral part of trout management in mountain lakes if a brood stock lake, similar to Heenan Lake for S. c. henshawi propagation, were established, since many mountain lakes lack adequate spawning area for trout of the genus Salmo to maintain self-reproducing populations, and must be stocked with trout fry dropped from aircraft. The potential of S. c. seleniris, as a rare and beautiful trout, to lure hikers to more remote and little-used areas of national forests could serve as a possible "crowd dispersal" technique in fishery and wilderness management.

Streams with natural barriers and small lakes having potential spawning tributaries but now harboring non-native trouts should be considered for chemical treatment to eliminate present trout populations and to establish additional self-perpetuating populations of S. c. seleniris.

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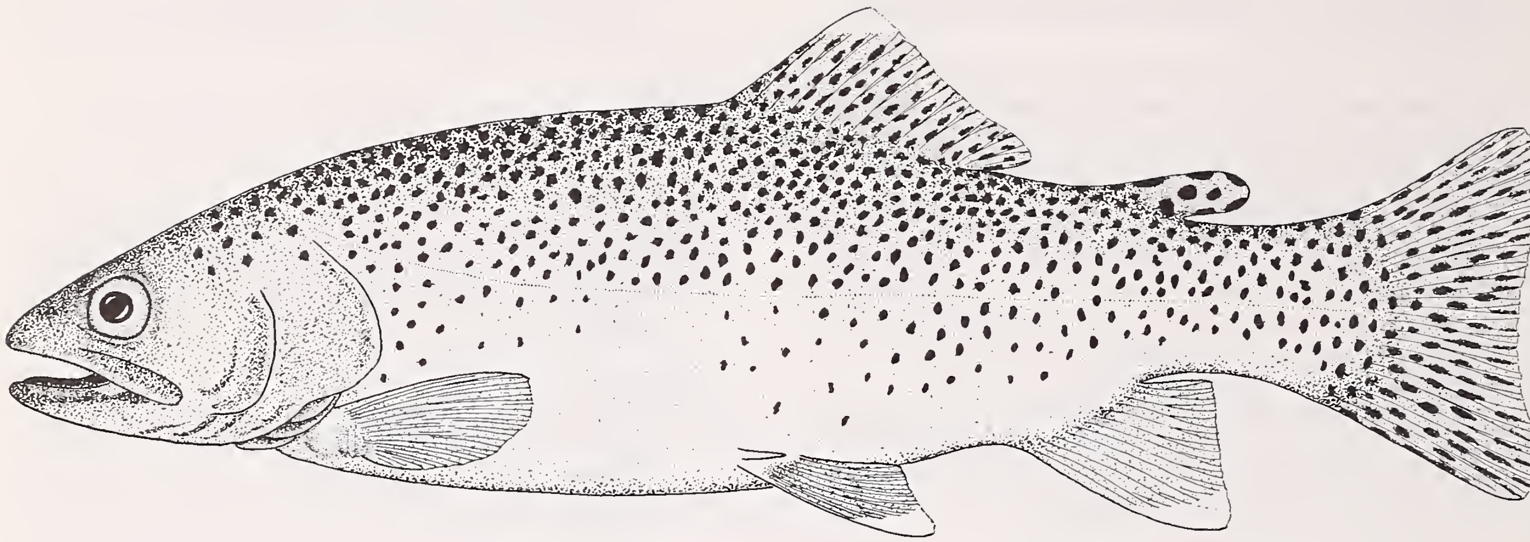


GILA TROUT
Salmo gilae

TYPICAL MERISTIC CHARACTERS

Scale counts	
lateral series (two rows above lateral line)	135-165
and above lateral line (origin of dorsal fin to lateral line)	29-38
Vertebrae	59-63[a]
Pyloric caecae	25-46 (means 33-36)[b]
	43-57 (mean 47.2)[c]
Basibranchial teeth	Absent[d]

[Taxonomic data from Behnke (1973) and personal data; and from David (1976).]

[a]Mean values for samples from four localities range from 59.7 for Spruce Creek specimens to 61.7 for McKenna Creek specimens.

[b]Values from specimens from Main Diamond, South Diamond and McKenna Creeks

[c]Values from specimens from Spruce Creek

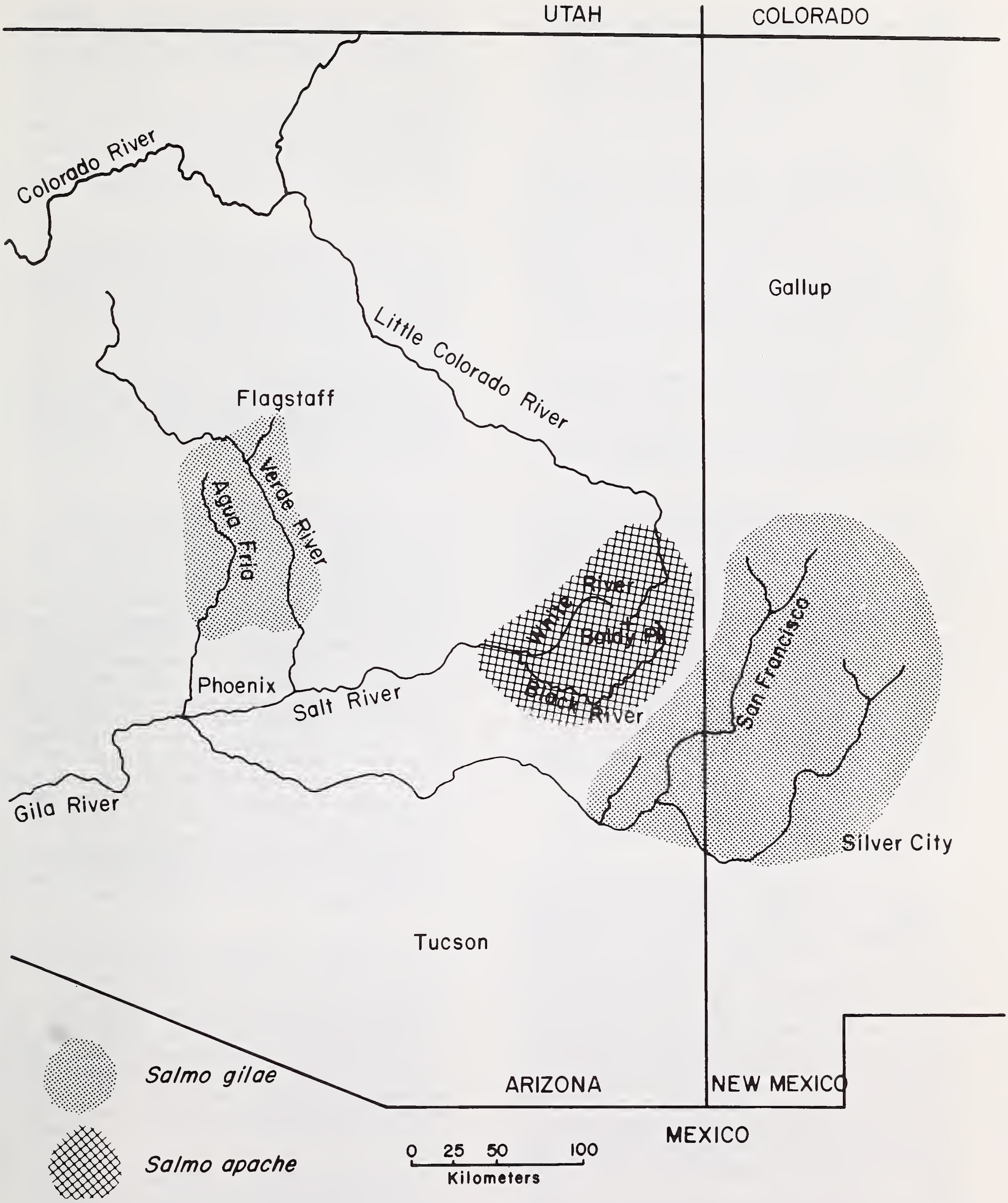
[d]Absent in all New Mexico specimens examined except those in Spruce Creek. Basibranchial teeth were also present in three of four specimens collected from Verde River drainage of Arizona in 1888-89.

SPECIES DESCRIPTION

Although a native trout was historically known from the Gila River basin of New Mexico, it was not until this trout was on the brink of extinction that it was recognized as distinct and described as a new species by R. R. Miller (1950).

A problem with providing an adequate diagnosis of Salmo gilae is that the original description is based on a population in tiny, intermittent Main Diamond Creek and certainly does not encompass the range of natural variability of this trout throughout its original range. Miller (1972) considered the original range of the Gila trout to include the Verde River system of Arizona (where the native trout is now extinct). Four specimens collected from Oak Creek, south of Flagstaff, in 1888 and 1889, and now in the U. S. National Museum, have the spotting pattern typical of the species (Miller 1972, fig. 5), but three of the four possess basibranchial teeth, a character not previously reported in S. gilae in the Gila River basin of New Mexico. However, David (1976) found basibranchial teeth in four of 12 specimens of Gila trout from Spruce Creek, a tributary of the San Francisco River system of New Mexico.

A distinctive feature of S. gilae is the profuse pattern of small, irregularly-shaped spots, mainly above the lateral line on the



Map 4. Indigenous distribution of Salmo gilae and Salmo apache.

body, onto the head, and on the dorsal and caudal fins. The basic coloration is yellowish or olive-yellow on the sides of the body; a faint rose band may be present along the lateral line in adults. A yellow cutthroat mark is present and the dorsal, anal and pelvic fins are tipped with white or yellow.

Salmo gilae is reputed to have a unique karyotype (number and morphology of chromosomes) which differentiates it from all other trouts (R. R. Miller, personal communication to R. Behnke). Mr. Robert David, New Mexico State University, has studied the chromosomes of S. gilae after completion of his thesis. Preliminary analysis indicates a karyotype different from any other trout (personal communication to R. Behnke).

Gila trout which have hybridized with rainbow trout are common in many tributaries of the upper Gila River. They exhibit erratic spotting and coloration, higher vertebral and caecal counts and lower scale counts.

DISTRIBUTION

Little information exists to accurately define the original distribution of the Gila trout. Miller (1950) documented its occurrence throughout the upper Gila River watershed downstream to the town of Cliff, New Mexico, in 1896, but it reputedly was absent from the San Francisco drainage of New Mexico and Arizona. Miller (1972) evaluated museum specimens collected from the Verde drainage, Arizona, a tributary to the Salt River of the Gila River basin, and pronounced them to be Salmo gilae. The present population of Gila trout in Spruce Creek, New Mexico, a headwater tributary in the San Francisco drainage, is attributed to an introduction in 1905 (Miller 1950).

The zoogeography of the distribution of S. gilae is puzzling. One would expect that S. apache, the native trout in the headwaters of the Salt River system, should also be the trout native to the Verde drainage of Arizona. And if S. gilae once had direct communication from the upper Gila basin of New Mexico with the Verde drainage of Arizona, why were no remnant populations discovered in the San Francisco River system? This distributional enigma is further compounded by the fact that the only known museum specimens of native trout from the San Francisco River system (K. P. Creek, Arizona) have the typical spotting pattern of S. apache (Miller 1972, fig. 4).

In 1975, trout specimens from Sycamore Creek, Arizona, a tributary to the Agua Fria River (the next drainage west of the Verde system), were collected by Mr. Gary Edwards of the Arizona Department of Game and Fish and sent to Robert Behnke for identification.

Although the Sycamore Creek population has hybridized with rainbow trout, enough of the original genotype remains to indicate that the native trout of Sycamore Creek had a spotting pattern typical of S. gilae.

Thus, S. gilae was probably native to both the Verde and Agua Fria drainages of Arizona. Needham and Gard (1959) described a trout from the Rio Yaqui of Mexico, a contiguous basin with the Gila River, which appears similar to S. gilae.

Unfortunately, the almost complete elimination of both S. gilae and S. apache from their native ranges before either of these species was studied, prevents a better understanding of their original distribution.

Presently, pure or essentially pure populations are known from Main Diamond, South Diamond and McKenna Creeks, New Mexico. The Spruce Creek population in the San Francisco drainage is attributed to an early introduction, but the lower number of vertebrae, higher number of pyloric caecae and the report of basibranchial teeth in specimens from this population indicate that Spruce Creek trout are well-differentiated from other S. gilae in New Mexico. This might be construed as evidence supporting the indigenous occurrence of S. gilae in the San Francisco drainage. Further support of such native distribution is given by the former occurrence of S. gilae in Eagle Creek, the next major tributary to the Gila River west of the San Francisco River (Mulch and Gamble 1956). David (1976) discovered a population of pure S. gilae in Iron Creek, an isolated tributary to the Middle Fork of the Gila River.

A cooperative project between the U. S. Forest Service, New Mexico Department of Game and Fish, and New Mexico State University introduced Gila trout from Main Diamond Creek into McKnight Creek of the Mimbres River basin in 1970 and 1972, after construction of a barrier and elimination of a sucker population. These trout have successfully reproduced (R. David and Douglas Jester, New Mexico State University, personal communication to R. Behnke).

Another project transplanted 89 Gila trout from Main Diamond Creek into barren Sheep Corral Creek, a tributary to Sapillo Creek in the Gila drainage, New Mexico.

Although stream improvement devices were placed into Sheep Corral Creek, the problem of livestock overgrazing remains and the degraded habitat has had no chance to recover. A 1975 survey of Sheep Corral Creek found 15 trout from the 1972 transplant, but no sign existed that successful reproduction had occurred. Probably S. gilae cannot become established in Sheep Corral Creek until the grazing problem is corrected (R. David, personal communication to R. Behnke).

The Arizona Game and Fish Department transplanted S. gilae from Main Diamond Creek, New Mexico into Gap Creek, a barren tributary of the Verde drainage in 1974, in an attempt to restore this species to the Verde system. A more ambitious program to restore the Gila trout to its historic range in Arizona was delayed by the loss of a hatchery brood stock in 1974 (Gary Edwards, Arizona Game and Fish Department, personal communication to R. Behnke).

STATUS AND POPULATION TREND

Miller (1950, 1961) described the former abundance and rapid decline to almost extinction of S. gilae. Hybridization throughout the upper Gila basin resulting from the introduction of rainbow trout was so extensive that by 1950 the very few pure populations of Gila trout which remained were all isolated by barriers in small headwater streams. Subsequent re-introduction programs in New Mexico and Arizona have met with modest success and the distribution and abundance of this rare trout have increased in recent years.

Salmo gilae is officially recognized as an endangered species under the Endangered Species Act of 1973.

LIFE HISTORY

Two Master of Science theses have been prepared on the Gila Trout of Main Diamond Creek (Regan 1964, Hanson 1971). Although these studies present detailed information on age, growth, food habits and fecundity of the trout and on physical, chemical and biological parameters of the water, this information reveals but certain life history characteristics as determined by the harsh environment of Main Diamond Creek. These studies are of limited value in predicting adaptability to new waters except to indicate that a trout which can thrive in Main Diamond Creek is likely to do well in almost any trout habitat, as long as no other fish are present. The growth potential of S. gilae almost certainly is greater than the 23 cm maximum size it attains in Main Diamond Creek.

Most probably, the original S. gilae found in the upper Gila basin did not consist of a single homogeneous population, but instead was composed of several discrete stocks in the smaller tributaries and probably another stock utilizing the main river and larger tributaries; these separate stocks probably possessed slightly differing life history characteristics. The assumption of discrete populations and genetic heterogeneity is supported by the taxonomic differences found between existing populations, particularly when Spruce Creek specimens are compared with other samples of S. gilae.

HABITAT REQUIREMENTS AND LIMITING FACTORS

Present S. gilae populations appear sufficiently adaptable to live in any waters suitable for any species of trout, even though originally this species probably consisted of disjunct populations with differing ecological specializations. A major limiting factor, though, remains the presence, in potential Gila trout habitat, of other species of trout; rainbow trout hybridize with S. gilae and brook and brown trout compete with it for food and space. Any stream presently holding brook, brown, or rainbow trout can provide suitable habitat for S. gilae after all exotic trouts are eliminated and prevented from re-invasion.

PROTECTIVE MEASURES

Main Diamond, South Diamond, McKenna, Iron and Spruce Creeks are in the Gila Wilderness Area of the Gila National Forest; thus they are endowed with some extra legal protection from habitat degradation.

The "endangered" status granted the Gila trout under the Endangered Species Act of 1973 prohibits its "taking" or "harassment," but prohibiting angling for an endangered trout, particularly in remote areas, may not be relevant to the protection of the species except in a negative way, since any large-scale restoration effort must be based on introduction into public waters. Subsequent closure of such waters to angling can create unfavorable response to such projects and inhibit realization of the desired goal. However, due to the extreme rarity of S. gilae, it may not be wise to remove the species from

the endangered list until the Little Creek restoration project has been successfully completed.

McKnight Creek has suffered habitat degradation from livestock overgrazing. The U. S. Forest Service initiated corrective measures in 1975 and also plans to institute grazing control in the Sheep Corral watershed in 1976 (Douglas Jester, personal communication to R. Behnke).

The Gila trout recovery team has drafted an outline of a Gila trout recovery plan (January 19, 1976). Included in the plan is a re-introduction of S. gilae into Little Creek after construction of a barrier and elimination of hybrids.

The Arizona Department of Game and Fish plans to re-establish a brood stock of Gila trout for introductions into the Verde and, perhaps, Agua Fria drainages (G. Edwards, personal communication to R. Behnke).

Section 7 of the Endangered Species Act of 1973 directs all federal agencies to carry out programs for conservation of endangered and threatened species and to prevent any of their activities from jeopardizing the continued existence of these species.

RECOMMENDATIONS

If the Little Creek restoration project meets with success, the Gila trout should be changed in status from "endangered" to "threatened." This change will facilitate management of the species and stimulate further transplants into public waters.

The population in South Diamond Creek exhibits the most uniform appearance of all known existing populations of S. gilae; as the most ideal representative of the species, at least some future transplants should be made from this population.

Robert David's research has revealed some populations of trout which, although slightly hybridized, exhibit a predominant S. gilae phenotype. Such populations should be protected against future introductions of non-native trout.

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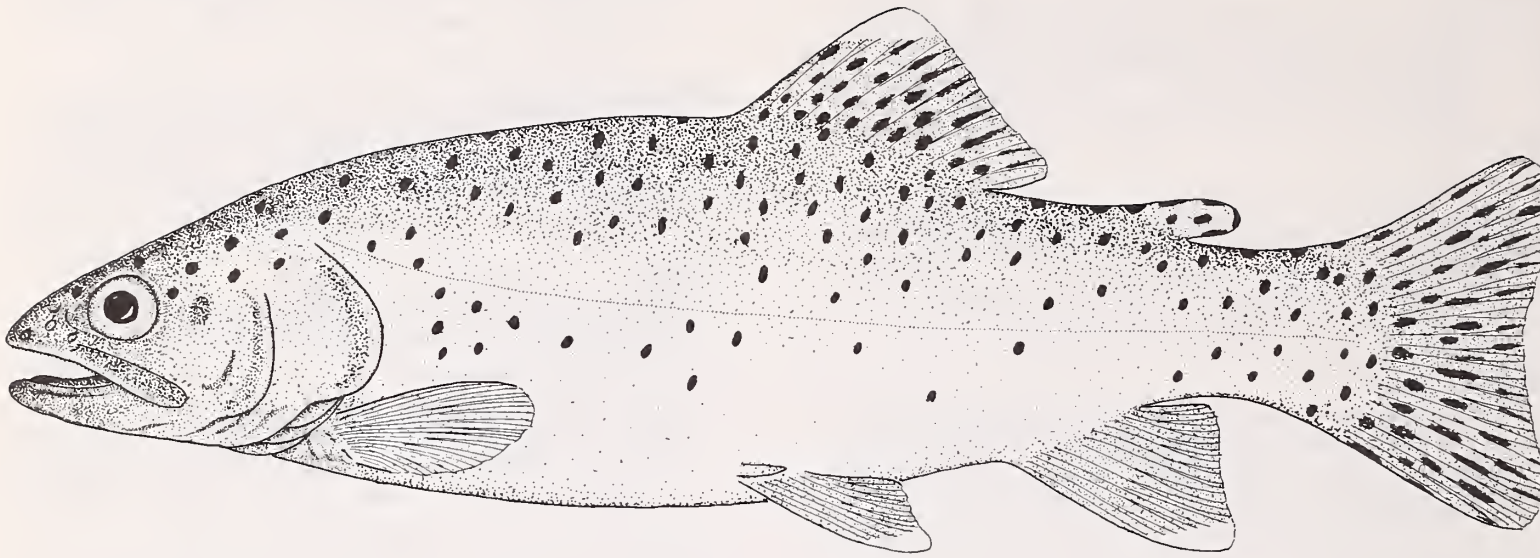

ARIZONA NATIVE TROUT
Salmo apache

TYPICAL MERISTIC CHARACTERS

Scale counts	
lateral series (two rows above lateral lines)	133-172 (mean 146-158)
and above lateral line (origin of dorsal fin to lateral line)	32-40 (mean 34-36)
Vertebrae	58-61 (mean 59.5-60)
Pyloric caecae	21-41 (mean 26.7-32.9)
Basibranchial teeth	Vestigial

SPECIES DESCRIPTION

Pyloric caecae counts are among the lowest of American trouts; basibranchial teeth are vestigial, with only five to 10 percent of the specimens of some populations possessing these teeth (Behnke 1970, 1973, personal data).

The basic coloration of Salmo apache resembles that of S. gilae, with olive-yellow to golden-yellow on the sides and ventral region, a yellow cutthroat mark and whitish tips on the dorsal, pelvic and anal fins. While S. apache lacks the rose-red lateral band typical of S. gilae, the spotting pattern constitutes the most pronounced phenotypic difference between the two trouts. S. apache displays larger roundish or oblong spots, similar to interior cutthroat trouts, over the sides of the body, onto the top of the head and on the dorsal, caudal and adipose fins (Miller 1972, fig. 2). S. apache typically possesses the largest dorsal fin of any American trout.

The unique karyotype of S. apache shows 56 chromosomes with 106 arms, and may be derived from a cutthroat trout-like ancestor (Miller 1972).

DISTRIBUTION

Cope and Yarrow (1875) first recorded trout in the White River, Arizona (in the headwaters of the Salt River system of the Gila River Basin) in 1873, and referred to them as a variety of the Colorado River cutthroat trout. Jordan and Evermann (1896) referred to the trout in the headwaters of the Little Colorado River in Arizona also as the Colorado River cutthroat. When Miller (1950) described S. gilae, he also mentioned native trout in the headwaters of the East Fork of the White River in Arizona and provisionally included them with the Gila trout as S. gilae. After further study and examination of many more specimens Miller became convinced of the uniqueness of this trout and described it as a new species, Salmo apache (Miller 1972).

By this time, the range of S. apache had been so diminished that the original

distribution was impossible to determine with certainty. Miller (1972) considered its native range to include the upper Salt River system of Arizona (Black and White River drainages) and the headwaters of the Little Colorado River. A museum specimen taken in 1904 from K. P. Creek, a tributary of the Blue River of the San Francisco drainage of Arizona, shows spotting patterns characteristic of S. apache and not S. gilae (Miller 1972, fig. 4). Perhaps both species were native to the San Francisco drainage of Arizona, but in this case it would be expected that hybridization between them would have produced an array of intergrading populations.

The present known natural distribution of S. apache includes: Ord Creek, Firebox Creek, Deep Creek, and headwaters of the East Fork of the White River; the upper Bonito Creek watershed, a tributary to the Black River. All of these streams are on the Fort Apache Indian Reservation. The only known population of S. apache in the Little Colorado River basin exists in Paddy Creek, between the towns of Alpine and Nutrioso, Arizona, near the New Mexico border. A survey conducted in 1967 by John Anderson, U.S. Fish and Wildlife Service biologist, and Robert Behnke determined that recently introduced brook trout had become abundant in Paddy Creek. Thus, the outlook for the perpetuation of the only known population of S. apache in the Little Colorado River basin appears doubtful.

S. apache has been propagated at the Sterling Springs Hatchery, Arizona, and a population has been established in Christmas Tree Lake, a sport fishing lake created specifically for this species' restoration on the Fort Apache Indian Reservation. The Sterling Springs Hatchery is under renovation and a new brood stock is currently being established (Joe Stone, personal communication to Robert Behnke). The propagation and reintroduction program for S. apache conducted by the Arizona Department of Game and Fish has resulted in the establishment of new stream populations in Grant, Home, Mineral, and North Canyon Creeks and streams on Graham Mountain (Robert Jantzen, Director, Arizona Department of Game and Fish, letter to Lynn Greenwalt, Director, U. S. Fish and Wildlife Service; Joe Stone, personal communication to Robert Behnke).

STATUS AND POPULATION TREND

Even though S. apache possesses many distinctive characters including a unique chromosome complement, no genetic barriers exist against hybridization with rainbow or cutthroat trout. The introduction of rainbow trout into waters of the White Mountains of Arizona began hybridization which spread throughout the watersheds until only remnant pure populations of S. apache persisted in a relatively few headwater areas. Due to this precarious situation, the U. S. Department of the Interior listed the Arizona trout as endangered. But the endangered status interfered with management and restoration efforts and prohibited angling (Christmas Tree Lake on the Fort Apache Indian Reservation was constructed and stocked with S. apache for use as a native trout fishery), so the status of S. apache was officially changed from "endangered" to "threatened" (Federal Register 40 (137), 16 July 1975).

While S. apache has been virtually eliminated from its native range, it has survived in greater numbers than S. gilae. In some streams, such as upper Ord Creek, S. apache had been found to coexist in good abundance with both brown trout and brook trout. But 1974 electrofishing in Ord Creek showed brook trout to be dominant and Arizona trout, rare (Ron Gumtow, personal communication to Robert Behnke, 2 October 1975).

LIFE HISTORY

As Miller (1972) pointed out, almost nothing is known of the life history of S. apache except for the significant fact that its reproductive season and spawning behavior must be sufficiently similar to rainbow trout to permit hybridization. Not all S. apache populations are completely isolated from introduced trouts. But while brook trout, brown trout, rainbow trout, and rainbow X S. apache hybrids have replaced pure S. apache in larger streams at lower elevations and in disturbed habitat, S. apache has been able to survive with brook trout and brown trout in Ord Creek and has persisted in the headwaters of the East Fork of the White River and in the upper Bonito Creek watershed without protection by absolute physical barriers or from introductions of non-native trouts. Such situations resemble examples of native cutthroat trout maintaining their integrity in undisturbed headwater areas where they possess the most fit genotypes for colder waters and associated environmental conditions. Disruption and degradation of pristine headwater environments typically lead to hybridization with rainbow trout and/or replacement by brown trout or brook trout.

The growth potential of *S. apache* remains unknown, but the largest specimen known from Christmas Tree Lake, a spent female, measured 48.8 cm and weighed 0.9 kg (Ron Gumtow, personal communication to Robert Behnke).

HABITAT REQUIREMENTS AND LIMITING FACTORS

The introduction of non-native trouts may not pose as severe a threat to *S. apache* as it does to *S. gilae* in cold headwater streams as long as the integrity of the habitat is not violated. The complete replacement of *S. apache* at lower elevations and in disturbed areas demonstrates that this species is placed at a competitive disadvantage in such situations. The entire upper Bonito Creek watershed, which contains the most abundant populations of *S. apache*, is currently being logged. While guidelines for habitat protection have been provided to the logging operation, they have no legal standing and some damage to the stream has already occurred (Richard Baldes and Ron Gumtow, personal communication to Robert Behnke). The impact of logging on the Bonito Creek watershed and on *S. apache* is under study, but data sufficient for basing forecasts are not yet available.

PROTECTIVE MEASURES

The Apache Indian Tribe has closed the waters of Ord Creek to fishing in order to protect the Arizona trout.

The Office of Endangered Species, U. S. Department of the Interior, lists *S. apache* as a threatened species (Federal Register 40 (137), 16 July 1975).

The Arizona Department of Game and Fish has propagated *S. apache* at their Sterling Springs hatchery from brood stock developed from Ord Creek trout. At least four new stream populations have been established. The brood stock was lost in 1974 but the hatchery is undergoing renovation and a new brood stock is being established (Gary Edwards, Joe Stone, personal communications to Robert Behnke).

Bruce Rosenlund (U. S. Fish and Wildlife Service, Alchesay-Williams National Fish Hatchery, Whiteriver, Arizona) has been conducting disease and parasite studies on *S. apache* to determine the presence of fish pathogens which could be serving as limiting factors to endangered populations in the wild, and to determine the feasibility of transferring endangered fish to a hatchery for propagation.

Ken Harper (Arizona Cooperative Fishery Unit, USDI, 210 Biological Sciences East, University of Arizona, Tucson, Arizona, 85721) is conducting graduate research to determine the effects of logging on *S. apache* in the Bonito Creek watershed. This project, initiated in 1974, is due for completion in 1976.

RECOMMENDATIONS

The Apache Indian tribe has, in the past, demonstrated a sincere interest in perpetuating the Arizona trout, but the recreational resources of the reservation are nonetheless a business enterprise and heretofore the tourist fishery has been based mainly on stocking great numbers of rainbow trout, particularly in a series of recreational lakes created on the reservation.

Ronald Gumtow, biologist with the U. S. Fish and Wildlife Service and advisor on fisheries management to the tribe, stresses a greatly expanded emphasis on the use of *S. apache* in sport fisheries management on reservation waters in the future. The former endangered status of *S. apache* prohibited angling and voided any economic gains to the tribe from the potential fishing in Christmas Tree Lake. Now that the status of *S. apache* has been changed from endangered to threatened, the lake can be opened to fishermen (for a fee) and similar fisheries for *S. apache* can be established.

The emphasis on native trout fisheries versus hatchery trout fisheries is one of quality versus quantity; the greater value lies with trout in the water rather than trout in the creel. The economic rationale is that with proper publicity and public interest, the tourist fisherman will be willing to pay more for the opportunity to fish for a rare and beautiful native trout than to fish for the common hatchery rainbow trout.

Before *S. apache* can be widely used to create new fisheries in reservation lakes, data must be gathered from Christmas Tree Lake on age, growth, vulnerability to exploitation and population structure under exploitation to provide information on optimum stocking rates and to design special regulations on size and bag limits to maintain maximum recreational values.

The watersheds of streams on the Apache Reservation and elsewhere with populations of *S. apache* should be granted special protection from possible future despoilation, comparable to wilderness areas of national forests.

Off the reservation, the reintroduction of S. apache into barren streams and recreational lakes should be stepped up. This recommendation is, in part, dependent on the success of hatchery propagation.

Paddy Creek, the only known locality in the Little Colorado River basin with a native population of S. apache, should be monitored to determine the impact of brook trout on S. apache. The 1967 survey of Paddy Creek by Anderson and Behnke noted that the headwaters above a barrier falls were barren of all fish. If S. apache still exists in Paddy Creek, a transplant above the barrier should be made as soon as possible.

Specimens from previously unsampled localities should be evaluated for relative purity in an attempt to discover new populations of S. apache.

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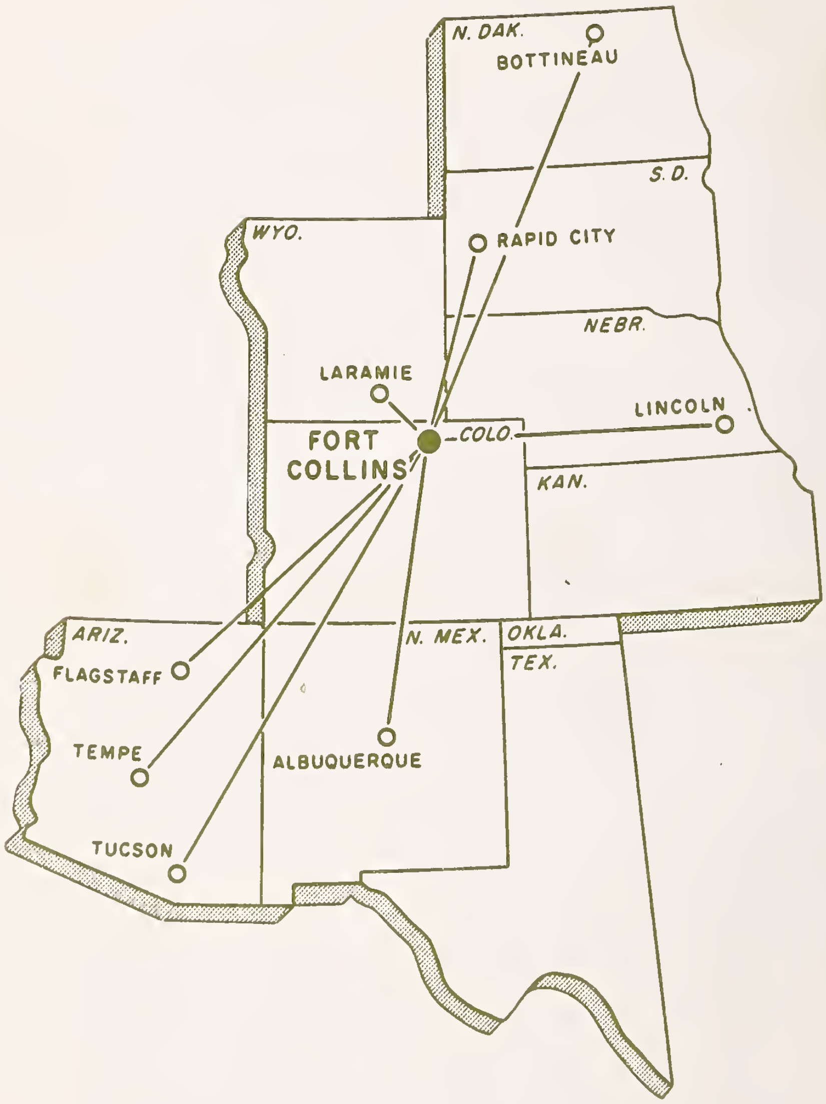
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